Retention of Pre-construction Primer in Tank Coating Systems

NSRP Project 3-96-3

November 2002

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Report Documentation Page						*Form Approved OMB No. 0704-0188*
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1. REPORT DATE **NOV 2002**		2. REPORT TYPE **N/A**				3. DATES COVERED **-**
4. TITLE AND SUBTITLE **Retention of Pre-Construction Primer in Tank Coating System**						5a. CONTRACT NUMBER
						5b. GRANT NUMBER
						5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)						5d. PROJECT NUMBER
						5e. TASK NUMBER
						5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Surface Warfare Center CD Code 2230-Design Integration Tools Bldg 192, Room 128 9500 MacArthur Blvd Bethesda, MD 20817-5700**						8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)						10. SPONSOR/MONITOR'S ACRONYM(S)
						11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release, distribution unlimited**						
13. SUPPLEMENTARY NOTES						
14. ABSTRACT						
15. SUBJECT TERMS						
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON	
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**93**		

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

FOREWORD

The research objective of this project was to test and evaluate the retention of pre-construction primers (PCP) as the first coat of high performance lining systems in ships' ballast tanks. Four different PCP's and six lining systems were tested. All materials tested were standard, commercially available products. No materials were specially formulated to accommodate the test program.

The major finding of this study is that PCP does not appear to compromise the performance of high performance ballast tank lining systems.

This research work was funded through the National Shipbuilding Research Program, Advanced Shipbuilding Enterprise (NSRP/ASE) under the technical direction of Technical Panel SP-3, Surface Preparation and Coatings Panel. The following Steering Committee Members provided valuable input and direction to the project:

Ms. Judie Blakey – General Dynamics National Steel & Shipbuilding
Mr. Steve Cogswell- Formerly of Atlantic Marine
Mr. Scott DeVinney - Formerly of General Dynamics Bath Iron Works
Mr. Walt Fortenberry- Northrup-Gruman Newport News Drydocking & Shipbuilding
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Special acknowledgement is also given to Mr. Michael Ayres, National Steel & Shipbuilding's Project Engineer, who made this project successful and the following coating suppliers who gave both materials and technical direction to the project:

Ameron
International Paint Company
Jotun
Hempel
Sherwin Williams
Sigma

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EXECUTIVE SUMMARY

The overall objective of this project is to investigate the feasibility of retaining pre-construction primer (PCP) as the permanent primer for protective coatings systems applied in ballast tanks. Should the retention of PCP be proven as a viable option, then the process of coatings application in US shipbuilding can be improved resulting in cost savings. New construction dollars will not be spent to remove the PCP prior to the application of high performance, salt water, ballast tank lining systems.

Europe leads the World in the development of the new high performance, immersion grade, marine coating systems. Asia and the Pacific Basin areas are believed to be more advanced in process and equipment development but not as advanced in new coatings development. One reason for this could be the commercial pressures in Asia to produce a less expensive ship. Process and equipment improvements reduce man-hours; whereas, high performance coating systems can increase initial cost, but can reduce maintenance cost and increase ship availability through extended drydocking intervals.

The results of this project firmly support the position that the use of a pre-construction primer does not degrade the overall performance of the ballast tank, protective-coating system. No failures during the testing phase were attributable to the use of a pre-construction primer. Europe and especially Asia retain the pre-construction primer as an integral production process to reduce ship costs and reduce ship construction cycle time. In the United States, this process is also beginning to gain favor and on several recent new builds, pre-construction primer has been retained in ballast tanks.

Summarized below are the general findings of this project:

- No edge failures were observed in any of the tanks lined with high solids linings.
- No edge failures were observed in the tank lined with medium solids linings.
- Most failures were associated with welds that had been power tool cleaned during secondary surface preparation.
- Some cracking at welds was observed in the tanks coated with high solids linings.
- Minor blisters were noted in two small, under thickness areas in the MIL-P-23236 Control Tank and one small area on the bottom flat of the MIL-P-24441 Control Tank.
- No blistering was noted for lining systems applied over PCP.
- With the exception of weld areas, the MIL-P-23236 qualified control system performed as well over PCP as when applied over SSPC-SP-10 abrasive blasted steel.
- The lower solids (67%) coating system performed at least as good as the high solids systems.
- The poorest performing system (Tank B-3) can be partially attributed to incomplete application.
- Attention to detail in applying the test coatings improved overall performance.
- The full thickness waterborne high ratio inorganic zinc coating provided four years of protection but was beginning to fail by erosion, especially around the fill and drain ports.

- The coating system applied in Tanks B-1 and C-2 was subsequently withdrawn from the market due to manufacturing problems.
- Zinc loading of the PCP did not appear to be a factor in the lining system performance.

Three direct benefits can be realized from the results of this project. These include:

- Proof that PCP does not degrade performance
- Elimination of cost to remove the primer prior to application of specified tank-lining systems
- Improved (reduced) shipyard throughput time
- Waste reduction-disposal of contaminated abrasives

Shipyards should evaluate the economic advantages of retaining pre-construction primer in ship's ballast tanks. Based on the results of this study, secondary surface preparation should consist of abrasive blast cleaning of welds and damaged areas.

Early in the project, a trip was scheduled to several European shipyards, coating supplier and the MARINTEK testing facility. Appendix A contains the results and findings of those visits.

TABLE OF CONTENTS

1.0 INTRODUCTION AND BACKGROUND

In the 1960's many shipyards routinely applied pre-construction primer (PCP) to stock plates and shapes using automatic abrasive blast cleaning and primer application equipment. These materials were either proprietary organic coatings or federal specification materials such as TT-P-664. This technique was cost effective and complimented the shipyard manufacturing methodology. At the discretion of the chief welding engineer, the primer was generally removed for automatic welding processes but normally welded through for stick processes.

The PCP primer, sometimes referred to as the prefabrication primer, was only removed to apply specified coating systems, which were known to be incompatible with the primer, such as, inorganic zinc. Many of the tank coating systems could be applied over the PCP after using hand tools to repair burned and mechanically cleaned areas. This system worked fairly well as long as the same paint manufacturer supplied both the primer and tank coating system.

While some epoxy primers offered good recoatability for epoxy tank linings, there have been some cases where catastrophic tank lining failures have resulted from applying epoxy tank linings over primers based on alkyd or epoxy ester formulations. Standard zinc load inorganic zinc PCP’s was also used to reduce the amount of primer failure during the manufacturing cycle. Applying epoxy tank linings and other immersion grade coatings over these standard inorganic zinc primers achieved mixed results. Sometimes this approach worked, but many times premature coatings failures resulted.

In 1985, the NSRP Panel SP-3 formulated a test program (NSRP Report 0248) to determine compatibility of inorganic zinc primers topcoated with epoxy coatings in immersion service. The results of this program were inconclusive. Some systems had good performance while others failed. No correlation was established between zinc loading and early failure.

During the evolution of PCP, the Japanese used modified organic resin binder systems in conjunction with metallic zinc pigments as primers. The zinc loading was much reduced compared to standard inorganic zinc primers and probably encapsulated the zinc pigment in an organic matrix. Some success was achieved with this approach; however, the necessary weld speed and quality were in question.

As weld speed increased, some yards switched from pre-priming prior to fabrication to applying the prime coat in the block stages. Some American yards used PCP’s but totally removed the primer prior to applying inorganic zinc and epoxy tank coatings either at block stages or after final erection. Many times, applying Navy specified coating systems also required the complete removal of any PCP prior to the application of inorganic zinc primers in the weather exposed areas and epoxy in immersion areas. This further caused U.S. yards to reduce the use and retention of pre-primers applied by automatic means.

While U.S. yards were switching from prefabrication priming to block priming, Japanese and other Asian yards and many European yards still used and continued to perfect prefabrication primer techniques. Once the primer was applied, it was not removed except in those cases where the owner was willing to pay a premium in cost and/or schedule.

Today, the trend in this country is to return to automatic PCP application especially in the reemerging commercial shipbuilding market. The introduction of primers that are reported to be capable of being welded through without detrimental effect also increased the attractiveness of this approach. Pre-priming can be accomplished for cents per square foot; whereas, open abrasive blasting and priming on blocks (modules), with the inherent negative environmental and regulatory impact, can cost dollars per square foot.

1.1 PCP Selection Criteria

PCP shop primers should be selected to be compatible with the manufacturing philosophy. High performance coating systems should then be selected to be compatible with the PCP and should include the necessary secondary surface preparation. In other words, PCP should be considered as any other substrate, which requires coating. To reduce total installed cost, the selection of the PCP cannot be driven just by performance of the primer as an undercoat for a high performance coating system. Failure to follow this rule will cause the loss of the advantage gained in using PCP’s. The PCP selection should be driven primarily by process considerations. These criteria include:

- Protection of the steel substrate during the fabrication cycle
- Affect on burning speeds
- Affect on welding speeds, processes, and resulting weld quality
- Burn-back
- Health and Safety
- Workplace lighting and cleanliness
- PCP film formation at reduced film thickness
- Suitability for application in automated facilities
- Performance as the primer in the high performance coating system

PCP formulation determines both long term corrosion protection and impact on fabrication processes. Zinc loads influence corrosion protection. The higher the zinc loads (content), the better the corrosion protection during fabrication. However, increased zinc loads have been shown to reduce the cutting and burning speeds. Health hazards are also increased with increasing zinc content. Zinc oxide formation during cutting and burning and worker exposure becomes an issue. Inorganic binder systems and proper pigment selection reduces burnback. Several coating manufacturers’ have overcome these challenges and have formulated acceptable materials.

1.2 Process Controls for Dry Film Thickness

One of the most important process controls for the use of PCP is dry film thickness control. For proper performance during cutting and welding, the dry film thickness must be controlled within a very narrow range. Application must be controlled to result in a dry film thickness of between 0.5 to 1.0 mils (12 to 25 µm). Balanced against this low thickness to accommodate fabrication processes is the need to provide corrosion protection during fabrication and erection up to the time that high performance topcoats can be applied.

One PCP manufacturer reports reduction in welding speeds of 12% with a variance in dry film thickness of from 0.5 mils (12µm) to 0.8 mils (20 µm). In other words, an increase of 0.3 mils (8 µm) in thickness reduced the cutting speed from 26 inches (675 millimeters) per minute to 23 inches (600 millimeters) per minute. Similar reductions can be seen in welding speeds and quality. As an example, welding speeds for double fillet Flux Core Arc Welding (FCAW) went from 20 inches (525 millimeters) per minute down to 18 (450 millimeters) per minute with essentially the same variance in film thickness.

Now that dry film thickness control has been demonstrated to be a critical control parameter, how can it be assured that the correct thickness has been achieved? SSPC PA 2 is a generally accepted practice for measuring dry film thickness. This procedure requires that the profile of the prepared substrate be measured using the same instrument as will be used to measure the applied dry film thickness. Since the size distribution of the measured profile and the dry film thickness of an applied PCP overlap, the standard magnetic dry film thickness gage is limited in accurately determining dry film thickness of the PCP. With the 10% accuracy of the measurement instrument, the actual, precise thickness of the applied PCP cannot be readily determined even though a difference between the mean value of profile and the mean of measured dry film thickness can be demonstrated. This generates a challenge to develop a new method of measuring the dry film thickness of thinly applied coatings over the rough surface topography derived from abrasive blast cleaning of steel.

Even though no standard exists, there are two generally accepted measurement techniques. Both utilize smooth substrates. In one case, a smooth 18-gauge (1 millimeters thick) steel plate is primed and the thickness measured using a standard magnetic or fixed probe device. The size and shape of the plate should accommodate the overlapping spray pattern of the automatic application device. An example would be a 18 gauge cold roll sheet that is 4 inches (100 millimeters) wide by 20 inches long (500 millimeters). Sufficient readings should be recorded to obtain a good statistical average. The second case uses a smooth glass plate. The thickness of the glass plate is measured with a micrometer before and after PCP application. The difference is the dry film thickness measurement. The glass plate has the added advantage of being able to view the consolidation of the film by holding the coated glass plate in front of a bright light source.

1.3 Topcoat Selection Criteria

The selection criteria for topcoats to be applied over retained PCP should be essentially the same as the procedure normally followed when selecting any immersion grade coating material with one major exception. Exposure media, temperature, cycling, user friendliness, health, and safety aspects are all important; however, the use of the PCP introduces a new dimension. In the United States, most high performance immersion grade coating and lining systems are recommended for use over bare steel substrates prepared by abrasive blast cleaning. In Europe and Asia, it is common practice to retain and coat over the PCP. The PCP is just another substrate to coat. Coating systems can be formulated that can be applied over PCP; however, there should be objective evidence either in the form of service history or actual marine immersion exposure histories that the proposed system will perform satisfactorily over the PCP. Dry film thickness control of the PCP again becomes important. The internal tensile strength of the PCP is much less than most of the high performance epoxy topcoats. This characteristic, or limitation, is amplified as the dry film thickness increases. The wetting ability of the epoxy and the degree of shrinkage during cure are important attributes.

Some formulators and coating suppliers have reported improved coating system performance using a thin film, zinc-containing PCP because of the inhibiting nature of the zinc.

The important point is to select the coating system that is formulated for application over PCP. In Europe several coating suppliers have cross-qualified coating systems using PCP from different suppliers. This has been necessary because many of the shipyards purchase PCP primed steel plate directly from the steel supplier.

1.4 Secondary Surface Preparation and Stripe Coating

Secondary surface preparation can vary from complete removal of the PCP to the extensive use of hand power tool cleaning. The general practice in Europe is to abrasive blast clean welds and mechanically damaged and burned areas to SA2.5, “Very Thorough Blast-Cleaning” which is essentially equivalent to SSPC SP-10, “Near White Blast Cleaning.” Because of the harsh European winters, pre-erection assemblies (large block units) are processed inside large, environmentally controlled paint halls. The balance of the PCP is lightly (sweep) blast cleaned to remove dirt, markings, scuffmarks, and other contamination resulting from normal fabrication practices. A stripe coat is generally applied by brush to all sharp edges, welds, and cutouts after the application of the first coat of the lining system. The stripe coat is not applied first because of the potential for blush rusting and recontamination of the adjacent blast cleaned flat areas during stripe coat application and cure. Following assembly into the main ship configuration, major erection welds are power-tool cleaned to bright metal using composition wheels and sanding disks to reestablish a surface roughness.

1.5 Qualification Testing

Qualification (proof) testing, in lieu of long term service histories, is sometimes performed to establish confidence in the material selection process. There are two general types of proof testing of coating and lining systems. One is laboratory immersion testing using techniques such as NACE TM 01-74, “Laboratory Methods for Evaluation of Protective Coatings Used as Lining Materials in Immersion Service." The second is to perform mock-up testing using simulated conditions. While neither of these approaches exactly duplicates service conditions, both can provide valuable performance data, especially the mock-up testing technique. In this NSRP research program, mock-up ballast tanks were used to compare and verify performance. In Europe, many shipyards, coating suppliers, ship owners, and regulatory agencies recognize the value of mock-up testing. The MARINTEK Institute in Sandefjord, Norway has developed a recognized test protocol using mock-up ballast tanks. Using this test program, numerous European coating and lining systems have been tested and qualified for use over various PCPs. Candidate coating systems are tested both over bare substrate and over PCP. Normally, qualification testing consists of 180 days, 3 weeks cycles with 2 weeks immersion. The primary difference between the Marintek test protocol and the NSRP program, other than the shortened length of the test cycle, is that MARINTEK uses a wave tank to simulate the sloshing of water in the tank to simulate ship movement. The cyclic tank tilting is set at a constant rate of 22-25 waves per minute. This technique is important when testing soft coatings; however, in discussion at MARINTEK, the value of the water movement in accelerating coating failure of hard coatings, such as epoxy, was inconclusive.

2.0 Establishment of Test Protocol

2.1 Since the primary purpose of this project was to test a concept and not qualify specific coating systems, only pre-tested systems were selected for inclusion in the test program. Four PCP's were selected with zinc loading ranging from 28 percent to 52 percent for the solvent-based primers to 85 percent for the waterborne primer.

Six commercially available epoxies plus a MIL-P-24441, Type IV ballast tank lining system were selected for testing. Volume solids ranged from 67 percent to 100 percent.

Three of the six commercially available epoxy ballast tank systems had been tested and qualified to the MARINTEK ballast tank test protocol. Two of the systems had been both tested and qualified to "Near 100% Solids" epoxy requirements of MIL-P-23236 and MARINTEK. All the selected PCP's were standard off-the-self shop primers. One was and still is being used by NASSCO. One waterborne inorganic zinc system was included. Two controls were also included. One was a MIL-P-23236 "Near 100% Solids" epoxy, and one was qualified to MIL-P-24441, Type IV. Both controls were applied over Near White Blast Cleaned Surface, SSPC SP-10 with all the PCP removed. The MIL-P-23236 material was also applied over PCP. Table 1 shows the actual layout of the test program. Listed below are the actual products used:

Primers

- High Zinc Load - Jotun Valspar WB-14 (Waterborne)
- Medium Zinc Load - International Nippie Ceramo SW NQA990
- Low Zinc Load- Sigma Weld MCII (7177US)
- Medium Zinc Load - Hemple 1589

Topcoats

- Ameron 236ER Series Epoxy
- International 180 Series Epoxy
- Jotun 591 Series Epoxy
- Jotun WB 18 Inorganic Zinc
- Sherwin Williams Duraplate Primer/Duraplate UHS Epoxy
- Sigma Sigmaguard BT 7404/7451
- Hempel 1763 Series

2.2 Cathodic Protection

The use of sacrificial zinc anode cathodic protection was also considered when formulating the test protocol; however, the decision was made not to install anodes. It was believed that the lining systems would be more prone to early failure without cathodic protection.

The paper prepared by J. M. Keyman, et al, "The Effects of Overvoltage on Immersed Coating Performance," presents test data that inorganic zinc PCP's with cathodic protection performed at least as well as the standard epoxy systems applied directly over blasted steel.

TABLE 1 – TANK LAYOUT

Tank Assembly A

Tank A1	Tank A2	Tank A3
PCP #1 (52 % Zinc) Topcoat "A" (93% Volume Solids) • Secondary Surface Preparation SP-1/SP-11 • Apply Intermediate Coat • Stripe coat (brush)all welds and edges • Apply Topcoat	PCP #1 (52 % Zinc) Topcoat "B" (98% Volume Solids) • Secondary Surface Preparation SP-1/SP-11 • Apply Intermediate Coat • Stripe coat (brush)all welds and edges • Apply Topcoat	PCP #1 (52 % Zinc) Topcoat "C" (67% Volume Solids) • Secondary Surface Preparation SP-1/SP-11 • Apply Intermediate Coat • Stripe coat (brush)all welds and edges • Apply Topcoat

Tank Assembly B

Tank B1	Tank B2	Tank B3
PCP #2 (Waterborne) (85% Zinc) Topcoat "D" (98% Volume Solids) • Secondary Surface Preparation SP-1/SP-11 • Apply Intermediate Coat • Stripe coat (brush)all welds and edges • Apply Topcoat	PCP #2 (Waterborne) (85% Zinc) Inorganic Zinc Topcoat (85% Zinc) • Secondary surface preparation – Sweep blast PCP and full blast welds • Do **not** stripe coat edges • Apply one coat of full thickness Waterborne High Ratio Inorganic Zinc Silicate.	PCP #2 (Waterborne) (85% Zinc) Topcoat "E" (80% Volume Solids) • Secondary Surface Preparation SP-1/SP-11 • Apply Intermediate Coat • Stripe coat (brush)all welds and edges • Apply Topcoat

Tank Assembly C

Tank C1	Tank C2	Tank C3
PCP #3 (28% Zinc) Topcoat "F" (100% Volume Solids) • Secondary Surface Preparation SP-1/SP-11 • Apply Intermediate Coat • Stripe coat (brush)all welds and edges • Apply Topcoat **Mil-P-23236**	PCP #3 (28% Zinc) Topcoat "D" (98% Volume Solids) • Secondary Surface Preparation SP-1/SP-11 • Apply Intermediate Coat • Stripe coat (brush)all welds and edges • Apply Topcoat	Completely Removed PCP #3 Topcoat "F" (100% Volume Solids) • Remove PCP to SSPC SP10 • Apply Intermediate Coat • Stripe coat (brush)all welds and edges • Apply Topcoat **Mil-P-23236** **CONTROL TANK ONE**

Tank Assembly D

Tank D1	Tank D2	Tank D3
PCP #4 (49% Zinc) Topcoat "C" (67% Volume Solids) • Secondary Surface Preparation SP-1/SP-11 • Apply Intermediate Coat • Stripe coat (brush)all welds and edges • Apply Topcoat	PCP #4 (49% Zinc) Topcoat "A" (93% Volume Solids) • Secondary Surface Preparation SP-1/SP-11 • Apply Intermediate Coat • Stripe coat (brush)all welds and edges • Apply Topcoat	Completely Removed PCP #4 Topcoat Mil-P-24441 • Remove PCP to SSPC SP10 • Apply Intermediate Coat • Stripe coat (brush)all welds and edges • Apply Topcoat **Mil-P-24441, Type IV** **CONTROL TANK TWO**

3.0 Work Sequence For Fabrication and Coating of Tanks

3.1 Sequencing

To duplicate shipbuilding techniques and integration of the paintwork, the following work sequence was followed:

(a). Descaled all raw plate and shapes to a Near White Blast Clean surface, SSPC SP-10 using NASSCO's standard steel abrasives mix in the automatic blast facility.

(b). Cut plate and shapes and kit for priming and tank fabrication.

(c). Re-blast cleaned cut plates, shapes and test panels to Near White Blast Clean, SSPC SP-10 using NASSCO's standard steel abrasive mix (S230/S280) in the automatic blast facility.

(d). Hand spray-applied test primer to both sides of the plate and shapes. Each kit had a separate primer. Target primer dry film thickness range was 0.7 to 1.3 mils. See Table Two for actual thicknesses applied.

(e). Fabricated tanks assuring that the same primer was used in a given tank.

(f). Tightness tested each tank using NASSCO's standard pneumatic procedure.

(h). Allowed fabricated test tank assemblies to age for approximately 60 days.

(I). Applied candidate ballast tank test coatings to each tank as outlined in Table 1, Tank Layout Configuration. Repair primer was not applied to repair areas prior to applying topcoat systems.

3.2 Surface Preparation

Surfaces were initially abrasive blasted to SSPC SP-10 and verified using SSPC VIS 1-89.

Profile was measured for both the descaling operations in automatic facility and after second blast immediately prior to primer application using ASTM D 4417, Method C, Replica Tape

Secondary surface preparation of welds and damaged areas consisted of "Solvent Cleaning" per SSPC SP-1 followed by "Power Tool Cleaning to Bare Metal," SSPC SP-11 of weld areas and a combination of "Power Tool Cleaning" to SSPC SP-3 and SP-11 for damaged areas.

Control tanks were re-blast cleaned to "Near White Blast Cleaning," SSPC SP-10. All PCP was removed from these two tanks.

All edges were left as manufactured. No edges were radiused.

3.3 Primer Applications and Measurement

Because of the difficulty in setting up the production primer line, three of the four PCP's were hand sprayed.

The target dry film thickness range for each primer was 0.7 to 1.3 mils. The following measurement technique was followed using a Positector 6000 Magnetic Gauge.

(a). Calibrated measuring device in accordance with SSPC-PA2 dated June 1, 1996, using NIST Standard Reference Shims in the thickness range being measured.

(b). Measured the profile of the unprimed plates and shapes and recorded these readings which were then averaged and subtracted from the measured dry film thickness readings to convert to the actual thickness.

(c). After each primer was applied more readings were made than required by SSPC PA 2. Each flat surface and stiffener were measured on both sides. At least six (6) spot measurements (18 total) were made for each plate side. Each stiffener had a minimum of three spot (9 total) readings taken on each side. The specified thickness range was 0.7 to 1.3 mils.

TABLE 2 – PROFILE AND PCP THICKNESS MEASUREMENT

Profile	Profile Top PCP #1	Profile Bottom PCP #1	Profile Top PCP #2	Profile Bottom PCP # 2	Profile Top PCP #3	Profile Bottom PCP # 3	Profile Top PCP #4	Profile Bottom PCP #4
Max	2.100	1.750	1.800	2.600	2.200	2.100	1.450	1.750
Min	0.650	0.500	0.550	0.600	0.350	0.350	0.450	0.350
Mean	1.160	1.050	1.140	1.350	0.910	1.050	0.870	1.000
STD DEV	0.323	0.276	0.328	0.438	0.321	0.352	0.211	0.273
Dry Film Thickness	**PCP #1 DFT Top**	**PCP #1 DFT Bottom**	**PCP #2 DFT Top**	**PCP #2 DFT Bottom**	**PCP #3 DFT Top**	**PCP #3 DFT Bottom**	**PCP #4 DFT Top**	**PCP #4 DFT Bottom**
Max	2.500	2.000	3.500	4.000	2.100	2.500	3.600	3.400
Min	0.900	0.750	1.800	1.200	0.800	0.750	0.850	1.050
Mean	1.600	1.350	2.780	2.140	1.290	1.500	1.900	1.930
STD DEV	0.332	0.295	0.494	0.649	0.280	0.406	0.544	0.504
Delta Mean	0.440	0.300	1.640	0.790	0.380	0.450	1.030	0.930
Delta Max	0.400	0.250	1.700	1.400	-0.100	0.400	2.150	1.650
Delta Min	0.250	0.250	1.250	0.600	0.450	0.400	0.400	0.700

3.4 Weathering

Primer was aged for two months after tank fabrication.

3.5 Topcoat Application

In most cases, application was accomplished using standard yard equipment; however, in some cases the coating supplier provided special plural component equipment for the high solids formulations.

Application environmental conditions, temperature, relative humidity, dew point, surface temperature were measured and recorded in accordance with published standard shipyard procedures. No coatings were applied unless all environmental conditions meet the coating manufacturer's published requirements.

The dry film thickness of each coat and the total dry film thickness for the system were applied in accordance with the manufacturers' instruction. See Table 3 for actual thickness applied.

Holiday Test per ASTM D5162 was performed (100 percent) after final coat was applied. With the exception of Tank B-3, repair material was brush applied to pin holes.

Appendix D contains graphs of the applied dry film thickness of each lining system.

4.0 Ballast Test Cycle

Once pre-priming, tank fabrication, and topcoat application were complete, the coating systems were allowed to cure for a minimum of seven days prior to filling the mock-up test tanks with San Diego Bay seawater. The tanks remained full for twenty days. At the end of twenty days, the seawater was drained from the tanks, and the tanks were left empty for ten days. This constituted one ballast cycle. After sixty days, two cycles, the tanks were inspected. There were no significant failures at that time. The tank testing cycles were resumed and continued for four years, with inspections made at one-year intervals.

5.0 Evaluation Methods and Standards

The following inspection methods and standards were used to document results:

- SSPC-VIS 2 Standard Method of Evaluating Degree of Rusting on Painted Steel Surfaces
- ASTM D714 Evaluating Degree of Blistering
- ASTM F1130 Standard Practice for Inspecting the Coating System of a Ship
- Carrier Life Enhancing Repair (CLER), Aircraft Carrier Tank and Void Inspection Booklet

The new SSPC-VIS 2 contains photographs of four types or distributions of rusting – spot rusting, general rusting, pinpoint rusting, other rusting. The first step is to determine the rust distribution, i.e., spot, general, or pinpoint. The next step is to determine the rust grade by comparing the graded area to the photograph, which much closely matches the observed condition. A rust grade of 10 denotes no failure. Lower numbers denote higher the degrees of rusting. Each rust grade is associated with a percentage of failure. For example, rust Grade 7 –S is spot rust with 0.3%-rusted area. ASTM F1130 also uses a series of alphanumeric notations to describe the extent and degree of failure. CLER was developed as an easy, quick method of describing the overall condition of the tank lining system. The booklet contains four numeric Conditions, which range from minor failure to total failure of the coating system. This is a good document to provide meaningful data that can be used to plan tank-coating maintenance.

6.0 Evaluation Results

Table Two contains a detailed evaluation of each candidate test coating system. Appendix C contains photographs of each coating system tested. The most significant result of the test program is:

"The use of the PCP in conjunction with standard tank lining systems did not degrade the overall performance of the lining system."

6.1 TANK A

Tank A was pre-primed with a 52% zinc load, solvent-based material. All secondary surface preparation of welds and damaged areas was accomplished with power tools. Cell A-1 was topcoated with a 93 % volume solids epoxy from the same supplier as the primer. There were no significant failures in this cell. There were only a total of seven pinholes with rust in the entire tank.

Cell A-2 was topcoated with a 98% solids material. This material was qualified to Mil-P-23238 as a edge retentive epoxy. The material had also passed MARINTEK qualification. The only failure was associated with minor cracking at a weld on the right flat.

Cell A-3 was topcoated with a 67% solids material. Only three pinholes showed any rust. There was minor cracking at one weld.

In summary, all the linings in these tanks were providing excellent corrosion protection.

6.2 TANK B

Tank B was pre-primed with a waterborne, high ration inorganic zinc primer with high zinc loading (85%). All secondary surface preparation of welds and damaged areas was accomplished with power tools.

Cell B-1 was topcoated with a high solids (98% volume solids) topcoat from the same supplier. Because of manufacturing problems, this material was subsequently removed from the market. Most of the failures were associated with failure at the welds. Some cracking at welds was observed.

Cell B-2 was topcoated with a full thickness, waterborne, high ration inorganic zinc topcoat. There was some failure associated with some of the power tool cleaned welds; however, the primary failure mode was erosion and depletion of the zinc. The zinc acted as an anode, which sacrificed to the protected steel. Had a zinc anode been used in conjunction with this system, the system longevity would have increased. This was the case in a previous NSRP Tank Lining test program (3-93-1) where a solvent based inorganic zinc with zinc anode cathodic protection demonstrated no failure after six years of testing.

Cell B-3 was topcoated with an 80% solids material. Because of schedule constraints, this tank was not completed properly. Many pinholes and holidays were identified but not repaired prior to placing the tank under test. As a result, defects began to appear early in the program. The lesson learned here is that attention to detail in assuring the job is complete is at least as important as the lining selection. Unfortunately, this is the only tank coated with this product so that no comparisons could be made over an alternate PCP.

6.3 TANK C

Tank C was pre-primer with 28% zinc loaded PCP. The primer and Topcoat in C-1 were was from the same supplier. The secondary surface preparation in Cells C-1 and C-2 was power tool cleaning. Cell C-3 was completely reblasted to totally remove the PCP. The same MIL-P-23236 qualified edge retentive topcoat system was applied in both Cell C-1 and C-3, so that a comparison of the same material with and without PCP could be made. This material had also been tested and qualified by MARINTEK. Cell C-3 was one of the two controls.

The systems in Cells C-1 and C-3 performed essentially the same. Both tanks had cracking at the welds, except that there was more cracking at the welds in the tank where the welds had been power tool cleaned. There was no failure associated with the PCP since the failures were limited to repair areas, which had no PCP present. Some minor blistering was experienced in the control tank (C-3) but this was associated with areas of low film thickness. These two Cells provide conclusive evidence that the PCP does not degrade performance. It also demonstrates that secondary surface preparation should consist of reblast cleaning of welds and damaged areas.

The topcoat system applied in Cell C-2 was the same topcoat as that applied in Cell B-1, which was subsequently withdrawn from the market. The performance was essentially the same in C-2 and B-2. The conclusion could be drawn that the primer difference between tanks was not a determinate in the overall performance of this product; however, since the product was withdrawn, no firm conclusions can be drawn.

6.4 Tank D

Tank D was pre-primed with a PCP, which contained 49% zinc in the dry film. This was a solvent-based product. Cell D-1 was topcoated with a 67% solids material supplied by the same company as the PCP. This is the same system as applied over a different manufacturer's PCP in Cell A-3. The topcoat was tested and qualified by MARINTEK. Excellent performance was demonstrated in both Cells D-1 and A-3. Two points can be drawn from this. One is that the PCP does not degrade performance and second, high solids materials do not necessarily provide superior performance. The primary key is selecting a proven product and proper application with attention to detail.

Cell D-2 was topcoated with the same product as applied in Cell A-1. As with Cells D-1 and A-3, excellence performance was repeated in both Cells D-2 and A-1. Failure was limited to a few pinholes and mechanical damage.

Cell D-3 was the second control. In this case, MIL-P-24441, Type IV epoxy was applied directly over blast cleaned steel. The overall performance was acceptable but inferior to two of the high solids and one medium solids proprietary product.

6.5 Summary

This test program demonstrated the viability of using a PCP in conjunction with a high performance tank lining system. As a minimum, secondary surface preparation should consist of abrasive blasting of weld and damaged areas to SSPC SP-10, Near White Blast cleaning. An additional, but equally important finding, is that proper application and attention to detail are extremely important.

Table 3 – Four Year Test Results

Tank A1- Primer #1 (52% Zinc) & Topcoat A (93% Volume Solids) From Same Supplier						
Surface Preparation Initial: SSPC SP-10			Secondary: Power Tool, SSPC SP-3			Total Dry Film Thickness: 10-27 mils
Surface Graded	**ASTM D-610 Rust**	**ASTM F1130 Inspection**	**ASTM D-714 Blistering**	**CLER Condition**	**Edge Failure**	**Remarks**
Top - Flat	10	0	None	1	None	
Top - Stiffener	9S	1B	None	1	None	One pin hole at weld
Top - Fill Port	9S	1B	None	1	None	
Back - Flats	9S	1B	None	1	None	One pin hole at weld
Back - Stiffener (HP)	9S (UNDER)	1B	None	1	None	Two pin holes underside only
Bottom - Flats	9S	1B	None	1	None	Four pin holes
Bottom - Stiffener	10	0	None	1	None	Mechanical damage one spot (1/4 inch diameter)
Bottom - Drain	10	0	None	1	None	Rust stain only
Right Side - Flat	10	0	None	1	None	
Left Side - Flat	10	0	None	1	None	
Side Structure	10	0	None	1	None	
Front Flat	10	0	None	1	None	
Hatch	10	0	None	1	None	Rust stain only
Additional Remarks:						

Tank A2- Primer #1 (52% Zinc) & Topcoat B (98% Volume Solids) From Different Suppliers						
Surface Preparation Initial: SSPC SP-10			**Secondary: Power Tool, SSPC SP-3**			**Total Dry Film Thickness: 10-24 mils**
Surface Graded	**ASTM D-610 Rust**	**ASTM F1130 Inspection**	**ASTM D-714 Blistering**	**CLER Condition**	**Edge Failure**	**Remarks**
Top - Flat	10	0	None	1	None	
Top - Stiffener	10	0	None	1	None	
Top - Fill Port	9S	1B	None	1	None	
Back - Flats	10	0	None	1	None	
Back - Stiffener (HP)	10	0	None	1	None	
Bottom - Flats	10	0	None	1	None	
Bottom - Stiffener	10	0	None	1	None	
Bottom - Drain	10	0	None	1	None	Rust stain
Right Side - Flat	8G	6C	None	1	None	Failure limited to cracking at welds. SP-3 SP*
Left Side - Flat	10	0	None	1	None	
Side Structure	10	0	None	1	None	
Front Flat	10	0	None	1	None	
Hatch	10	0	None	1	None	Rust stain
Additional Remarks: Surface preparation at welds was SSPC SP-3, Power Tool Cleaning						

Tank A3- Primer #1 (52% Zinc) & Topcoat C (67% Volume Solids) From Different Suppliers						
Surface Preparation Initial: SSPC SP-10			**Secondary: Power Tool, SSPC SP-3**			**Total Dry Film Thickness: 11-20 mils**
Surface Graded	**ASTM D-610 Rust**	**ASTM F1130 Inspection**	**ASTM D-714 Blistering**	**CLER Condition**	**Edge Failure**	**Remarks**
Top - Flat	10	0	None	1	None	
Top - Stiffener	10	0	None	1	None	
Top - Fill Port	6S	4T	None	1	None	
Back - Flats	10	0	None	1	None	
Back - Stiffener (HP)	10	0	None	1	None	
Bottom - Flats	9S	1B	None	1	None	Three pin holes
Bottom - Stiffener	9S	1B	None	1	None	Mechanical damage - one spot
Bottom - Drain	10	0	None	1	None	Mechanical damage - one spot
Right Side - Flat	10	0	None	1	None	
Left Side - Flat	9S	1B	None	1	None	Cracking at weld
Side Structure	10	0	None	1	None	
Front Flat	10	0	None	1	None	Mechanical damage
Hatch	10	0	None	1	None	Rust stain
Additional Remarks:						

Tank B-1- Primer #2 (Waterborne)(85% Zinc) & Topcoat D (98% Volume Solids)						
Surface Preparation Initial: SSPC SP-10			**Secondary: Power Tool, SSPC SP-3**			**Total Dry Film Thickness: 15-18 mils**
Surface Graded	**ASTM D-610 Rust**	**ASTM F1130 Inspection**	**ASTM D-714 Blistering**	**CLER Condition**	**Edge Failure**	**Remarks**
Top - Flat	10	0	None	1	None	
Top - Stiffener	9S	1B	None	1	None	
Top - Fill Port	8T	2G	None	3	None	Threads only
Back - Flats	9S	1B	None	1	None	1 crack at weld 0.75 inches long
Back - Stiffener (HP)	9G	1B	None	1	None	
Bottom - Flats	9S	1B	None	1	None	
Bottom - Stiffener	9G	1B	None	1	None	Mechanical damage 3 spots
Bottom - Drain	10	0	None	1	None	Rust stains
Right Side - Flat	9S	1B	None	1	None	Some cracking around welds
Left Side - Flat	9S	1B	None	1	None	Most failures at welds
Side Structure	9S	1B	None	1	None	Failure at some welds
Front Flat	10	0	None	1	None	Mechanical damage at hatch
Hatch	10	0	None	1	None	Rust stains
Additional Remarks: Most failures are associated with welds, with some apparent cracking						

Tank B-2- Primer #2 (Waterborne)(85% Zinc)& Waterborne Inorganic Zinc Topcoat From Same Supplier						
Surface Preparation Initial: SSPC SP-10			Secondary: Sweep Blast SSPC SP-7			Total Dry Film Thickness: 2-3.4 mils
Surface Graded	**ASTM D-610 Rust**	**ASTM F 1130 Inspection**	**ASTM D-714 Blistering**	**CLER Condition**	**Edge Failure**	**Remarks**
Top - Flat	10	0	None	1	None	
Top - Stiffener	6G	10F	None	2	None	Major failure limited to top edge
Top - Fill Port	3G	7M	None	2	None	Threads only
Back - Flats	5P	11H	None	2	None	
Back - Stiffener (HP)	9S/5P	11H	None	2	None	Bottom 9S/Top 5P
Bottom - Flats	6P*	11H	None	2	None	Coating depleted in one square foot at drain
Bottom - Stiffener	1P/8P	11G	None	2	None	Top flange 1P/Underside1P/Back of web 8P
Bottom - Drain	10	0	None	1	None	
Right Side - Flat	7P	1C	None	1	None	Welds failed
Left Side - Flat	8P	1C	None	1	None	Mud cracking, excessive thickness in corner
Side Structure	8G	1D	None	1	None	
Front Flat	1P*	8P	None	2	None	Failure limited to drain area - erosion
Hatch	10	0	None	1	None	Rust stain
Additional Remarks: *Noted failures are localized to fill port and low thickness around hatch.						

Tank B-3- Primer #2 (Waterborne)(85% Zinc) & Topcoat E (80% Volume Solids) From Different Suppliers						
Surface Preparation Initial: SSPC SP-10			**Secondary: Power Tool, SSPC SP-3**			**Total Dry Film Thickness: 6-11 mils**
Surface Graded	**ASTM D-610 Rust**	**ASTM F1130 Inspection**	**ASTM D-714 Blistering**	**CLER Condition**	**Edge Failure**	**Remarks**
Top - Flat	6S	1N	None	2	None	Cracking around snipe. Starting to crack at weld. Backside in particular
Top - Stiffener	8S	5G	None	2	None	
Top - Fill Port	3G	11S	None	2	None	Total failure at threads
Back - Flats	6G	11G	None	1	None	Failure limited to cracking at welds
Back - Stiffener (HP)	8S	1B	None	1	None	One crack
Bottom - Flats	3S	11J	None	2	None	Failure limited to cracking at welds
Bottom - Stiffener	8S/3G/8G	6M	None	2	None	Flange top 8S/underside 3G/Web 8G
Bottom - Drain	10	0	None	1	None	
Right Side - Flat	9S	1B	None	1	None	Failure at welds
Left Side - Flat	3S	11J	None	2	None	
Side Structure	6G	7H	None	2	None	Failure limited to backside. Insufficient coating.
Front Flat	7G	8B	None	1	None	
Hatch	9G	11C	None	1	None	
Additional Remarks:						

Tank C-1- Primer #3 (28% Zinc) & Topcoat F (100% Volume Solids) From Same Supplier						
Surface Preparation Initial: SSPC SP-10			**Secondary: Power Tool, SSPC SP-3**			**Total Dry Film Thickness: 10-17 mils**
Surface Graded	**ASTM D-610 Rust**	**ASTM F1130 Inspection**	**ASTM D-714 Blistering**	**CLER Condition**	**Edge Failure**	**Remarks**
Top - Flat	9S*	1B	None	1	None	Minor cracking at welds.
Top - Stiffener	10	1B	None	1	None	1 crack 0.75 inches long, backside at weld.
Top - Fill Port	4G	4S	None	1	None	
Back - Flats	9S	1B	None	1	None	
Back - Stiffener (HP)	9S	1B	None	1	None	Failure limited to welds
Bottom - Flats	9S	1B	None	1	None	
Bottom - Stiffener	9S	1B	None	1	None	
Bottom - Drain	10	0	None	1	None	Rust staining only
Right Side - Flat	10	0	None	1	None	
Left Side - Flat	9S	1B	None	1	None	Cracking not associated with weld.
Side Structure	10	0	None	1	None	
Front Flat	9S	1B	None	1	None	Pinhole in weld, no rust.
Hatch	10	0	None	1	None	Staining only
Additional Remarks: *Failure associated with wet film thickness measurement. **Starting to observe micro cracking in some weld areas.						

Tank C-2- Primer #3 (28% Zinc) & Topcoat D (98% Volume Solids) From Different Suppliers						
Surface Preparation Initial: SSPC SP-10			**Secondary: Power Tool, SSPC SP-3**			**Total Dry Film Thickness: 11-20 mils**
Surface Graded	**ASTM D-610 Rust**	**ASTM F1130 Inspection**	**ASTM D-714 Blistering**	**CLER Condition**	**Edge Failure**	**Remarks**
Top - Flat	9S	1B	None	1	None	
Top - Stiffener	9S	1B	None	1	None	Cracking at welds.
Top - Fill Port	4G	4S	None	1	None	
Back - Flats	10	0	None	1	None	
Back - Stiffener (HP)	9S	1B	None	1	None	All failures are cracking at welds.
Bottom - Flats	9S	1B	None	1	None	Cracking at welds, back of tank.
Bottom - Stiffener	9S	1B	None	1	None	
Bottom - Drain	4G	11P	None	2	None	Extensive cracking around lip of drainpipe.
Right Side - Flat	9S	1B	None	1	None	Cracking adjacent to weld.
Left Side - Flat	9S	1B	None	1	None	All failures associated with cracks, one crack nine inches long.
Side Structure	10	0	None	1	None	
Front Flat	9S	1B	None	1	None	Cracking at welds.
Hatch	10	0	None	1	None	Rust staining only.
Additional Remarks:						

Tank C-3- Control One –Primer completely removed; Topcoat F (Mil-P-23236 Qualified)						
Surface Preparation Initial: SSPC SP-10			**Secondary: Primer completely removed, SSPC SP-10**			**Total Dry Film Thickness: 9-17 mils**
Surface Graded	**ASTM D-610 Rust**	**ASTM F1130 Inspection**	**ASTM D-714 Blistering**	**CLER Condition**	**Edge Failure**	**Remarks**
Top - Flat	8S	1B	None	1	None	
Top - Stiffener	9S	1B	None	1	None	Crack at weld, backside, and one inch long.
Top - Fill Port	3G	4S	None	1	None	
Back - Flats	10	0	None	1	None	
Back - Stiffener (HP)	9S(T)/3G(B)	8Q	None	1	None	
Bottom - Flats	9S	1B	None	1	None	
Bottom - Stiffener	10	0	None	1	None	
Bottom - Drain	10	0	None	1	None	Minor staining
Right Side - Flat	9S	1B	None	1	None	
Left Side - Flat	10	0	None	1	None	
Side Structure	8S	1B	None	1	None	
Front Flat	8G	1B	4M	1	None	Blistering limited to hatch area only, low thickness.
Hatch	9S	1B	6M	1	None	Blistering limited to bottom edge.
Additional Remarks: Some cracking, but very minor (one place).						

Tank D-1- Primer #4 (49% Zinc) & Topcoat C (67% Volume Solids) From Same Supplier						
Surface Preparation Initial: SSPC SP-10			**Secondary: Power Tool, SSPC SP-3**			**Total Dry Film Thickness: 10-17 mils**
Surface Graded	**ASTM D-610 Rust**	**ASTM F1130 Inspection**	**ASTM D-714 Blistering**	**CLER Condition**	**Edge Failure**	**Remarks**
Top - Flat	10	0	None	1	None	
Top - Stiffener	9S	1B	None	1	None	One spot at weld, undercutting.
Top - Fill Port	4G	4S	None	2	None	Failure limited to threads.
Back - Flats	10	0	None	1	None	
Back - Stiffener (HP)	10	0	None	1	None	
Bottom - Flats	9S	1B	None	1	None	One pin hole at drain hole.
Bottom - Stiffener	9S	1B	None	1	None	Limited to staining.
Bottom - Drain	9S	1B	None	1	None	
Right Side - Flat	10	0	None	1	None	
Left Side - Flat	10	0	None	1	None	
Side Structure	10	0	None	1	None	Mechanical damage
Front Flat	10	0	None	1	None	
Hatch	10	0	None	1	None	Rust staining only.
Additional Remarks:						

Tank D-2- Primer #4 (49% Zinc) & Topcoat A (93% Volume Solids)						
Surface Preparation Initial: SSPC SP-10			**Secondary: Power Tool, SSPC SP-3**			**Total Dry Film Thickness: 11-20 mils**
Surface Graded	**ASTM D-610 Rust**	**ASTM F1130 Inspection**	**ASTM D-714 Blistering**	**CLER Condition**	**Edge Failure**	**Remarks**
Top - Flat	10	0	None	1	None	
Top - Stiffener	10	0	None	1	None	
Top - Fill Port	10	0	None	1	None	
Back - Flats	10	0	None	1	None	
Back - Stiffener (HP)	10	0	None	1	None	
Bottom - Flats	9S	1B	None	1	None	
Bottom - Stiffener	10	0	None	1	None	
Bottom - Drain	10	0	None	1	None	Rust staining only.
Right Side - Flat	9S	1B	None	1	None	One small pin hole.
Left Side - Flat	10	0	None	1	None	
Side Structure	10	0	None	1	None	
Front Flat	10	0	None	1	None	Mechanical damage
Hatch	10	0	None	1	None	Rust staining only.
Additional Remarks:						

Tank D-3- Control Two - Primer completely removed; Topcoat- Mil-P-24441, Type IV						
Surface Preparation Initial: SSPC SP-10			**Secondary: SSPC SP-10**			**Total Dry Film Thickness: 10-17 mils**
Surface Graded	**ASTM D-610 Rust**	**ASTM F1130 Inspection**	**ASTM D-714 Blistering**	**CLER Condition**	**Edge Failure**	**Remarks**
Top - Flat	8G	1B	None	1	None	Failure at wet film thickness measurement.
Top - Stiffener	8G	1B	None	1	None	Insufficient film thickness.
Top - Fill Port	4G	8S	None	1	None	Failure on threads only.
Back - Flats	9S (T)/5S (B)	1B	None	1	None	
Back - Stiffener (HP)	9S	1L	None	1	None	
Bottom - Flats	9S	1B	4MD	1	None	Blister at front only.
Bottom - Stiffener	4G	8M	None	1	None	4-inch by 12-inch failure on backside.
Bottom - Drain	10	1B	None	1	None	
Right Side - Flat	10	0	None	1	None	
Left Side - Flat	9S	1B	None	1	None	Limited to weld area.
Side Structure	10(F)/3G(B)	8S	None	2	None	Failure limited to backside
Front Flat	5G	8H	None	1	None	Edge of hatch opening
Hatch	5G	2M	None	1	None	Limited to left edge only.
Additional Remarks:						

APPENDIX A

Survey of European Shipyards and Coating Suppliers

This section provides the results of the actions required by Task 2 of Phase 1 of the project deliverables. This Task consisted of discussions with both US and Foreign Shipyards and Paint Manufacturer's as to the feasibility of retaining the PCP.

The Task description called for a trip to Europe or Asia to gather first hand knowledge and experience in the use of PCP. Europe was selected because most of the new high performance, immersion grades coatings systems are being developed in Europe. Asia and the Pacific Basin areas are believed be more advanced in process and equipment development but not as advanced in new coatings development. One reason for this could be the commercial pressures to produce a less expensive ship with resulting shorter ship life cycles. Process and equipment improvements reduce man-hours; whereas, high performance coating systems increase initial cost.

Development of new, high performance marine coating systems in the United States has been at a virtual stand still. With most new builds being Navy ships which require the use of military specification coating systems, there has been little commercial incentive to develop new coatings technology, especially in ballast tanks. In ballast tanks this trend has been reversed; however, technology has not caught up with the change in direction.

Five marine coatings manufacturer's, three shipyards, and one testing institute were visited and data collected.

1.0 Survey Findings

1.1 Pre-Construction Primer (PCP) Utilization

1.1.1 None of the shipyard removed the Pre-construction Primer (PCP), nor did any of the coating manufactures recommend removal.

1.1.2 PCP was selected based on shipyard construction parameters, i.e. corrosion protection, weld type, and speed.

1.1.3 PCP was top-coated with a coating system that was qualified by the coating companies over PCP.

1.1.4 Primed steel was either purchased from French or Swedish steel companies, or coated in-house. The PCP was applied in a controlled process with Statistical Process Control (SPC) methods to include record keeping.

1.1.5 The minimum PCP thickness was determined based on the corrosion prevention performance and the maximum thickness was based on the cohesion properties of the PCP.

1.1.6 Primary surface preparation of the steel, in the automated abrasive line, used either shot or a shot/grit mix. The process was monitored using SPC techniques. There was a clear understanding of the relationship between the depth of the profile and the required dry film thickness (DFT).

1.1.7 The profile of the steel was measured using “Press-O-Film,” RUGOTEST 3, or KTA comparator.

1.1.8 PCP primed steel was color-coded to distinguish steel type.

1.1.9 PCP was welded through or was removed before welding based on shipyard construction practice. None of the three shipyards welded through the PCP 100 percent of the time.

1.1.10 PCP (and follow-on coats) was supplied to the shipyards in reusable totes. The PCP was always applied with airless spray equipment.

1.1.11 The thickness of the PCP was measured using both glass panels and smooth steel strips techniques. Two of the coating manufacturers recommended practices that used smooth steel strips. The use of the smooth steel strips also allows for the estimation of DFT when coating structural shapes (profiles).

1.1.12 One of the shipyards performed qualification tests for coatings in order to insure compatibility with yard construction processes.

1.1.13 The selection of PCP is based on:

- Required corrosion protection to match shipyard processes
- Welding/burning qualifications and speeds
- The ability to develop and control construction processes

2.0 Secondary Surface Preparation

2.1 Weld seams and any physically damaged PCP was blasted to SA 2 1/2, with the exception at one yard, where power tools were used to clean welds made on the construction way. Types of power tools included sanding discs, 3M Clean and Strip, and wire brushes.

2.2 Two of the yards had large combination blast and paint halls with the ability to apply finish coatings to tank, exterior topside, and underwater coating through the first coat of anti-fouling.

2.3 In all cases the PCP was sweep blasted with up to 50 to 70 percent of the PCP retained. Both expendable and reusable grit were used for the sweep blasting.

2.4 Waterjetting was prohibited at one of the yards because of difficulty in removing the moisture from the tank prior to coating.

3.0 Edge Preparation

There was no consistency in either the need to have the cut edges of the steel rounded or in the method used to round the cut edges. Single and double chamfering, radiusing, or a simple pass with a sander was used. One of the yards is working on developing a special power tool that would radius both edges at one time. In most cases, extruded edges were not radiused but left as manufactured.

4.0 Stripe Coating

All shipyards stripe coated, and all coating manufacturers had procedures for stripe coating that included using contrasting colors. The sequence of stripe coating varied, but all recommended that the first stripe coat be applied after the first top coat in order that the steel surface not be contaminated or the surface preparation lost. Stripe coating should always be done with a brush and never with a roller.

5.0 Surface Contamination

Only one yard took surface contamination readings prior to coatings application, and this was done only for sections delivered via barge from other fabrication sites.

6.0 Top Coating

6.1 Topcoats from various coating manufacturers were applied over the PCP without regard to the manufacture of the PCP.

6.2 All topcoats were measured for DFT.

6.3 All topcoats were light colored in ballast tanks based on recommendations by certification/standards agencies.

6.4 Soft and semi-hard coatings are no longer applied in Europe.

6.5 The number of coats to meet the specified DFT varied from 1 to 3 coats depending upon the customer.

6.6 The PCP was never completely removed.

6.7 100 percent epoxy tank coatings are not universally used. Some yards used lower solids tank coatings but all met local air quality requirements.

7.0 Cathodic Protection

7.1 One yard saw no benefit in installing anodes in new construction; whereas, one yard felt that it was necessary to install anodes in new construction in order to evaluate the coating at the initial survey.

7.2 All yards are presently using epoxy tank coatings; however, in the past, some have used full thickness inorganic zinc with success.

7.3 Some coating manufactures have done extensive cathodic disbondment testing with or without PCP. Presence of PCP did not degrade the testing results.

7.4 All PCPs were solvent based. All paint manufactures recommend 50 percent zinc by weight in the DFT to provide necessary protection. One yard was using a 75 percent coating.

7.5 No impressed current cathodic protection systems were being used.

8.0 Performance of Coatings

8.1 Coating system performance with retained PCP has been at least as good as where coatings were applied directly over blast cleaned steel. Two shipyards have tracked the performance over an extended time period. No difference in performance was noted when the PCP was retained.

8.2 At least two of the coating manufactures have developed a computer database to track coating performance as vessels are surveyed.

9.0 Welding

9.1 Submerged Arc Welding (SAW), Gas Metal Arc Welding (GMAW), and Flux Cored Arc Welding (FCAW) were observed in construction processes.

9.2 Two of the yards made extensive use of robotic welding due to the use of Accuracy Control.

9.3 One yard had small abrasive blasters installed on robotic welding lines that removed the PCP immediately prior to welding.

9.4 Burn through and heat affected PCP was negligible, thereby significantly reducing weld clean up.

9.5 In all cases the shipyards were concerned about the health effects of high zinc loaded PCP.

10.0 General Observations

Each shipyard and each coating manufacturer had a high degree of understanding of process control. All of the companies visited had a clear understanding of the need to identify and control PCP application, welding, and coating processes.

German shipbuilders have joined forces and developed industry specific standards for many procedures.

There is a general agreement in Europe between coating suppliers that PCP and coating systems can be interchanged between coating manufacturers. PCP is considered as just another substrate over which coating systems can be successfully applied.

11.0 Discussion Details

Monday May 18
Courtaulds Coatings
50 George Street
London, United Kingdom

Met with **Mr. Ian Thomas**, Director of Marketing for International Courtaulds Coatings Ltd. Worldwide Marine, at the headquarters in London, United Kingdom.

Mr. Thomas gave an overview of the International Courtaulds company. Mr. Thomas had reviewed the 3-96-3 Abstract and the proposal from Associated Coatings Consultants Inc. (ACCI) prior to this meeting. Mr. Thomas wanted to insure that the coatings applied to the test tanks were applied using "best practices" found in the field, and not those that would be found in the laboratory. We discussed exactly what those "best practices" were and how to document the coating applications.

I presented an overview of the history of National Shipbuilding Research Program (NSRP) and ACCI's past and current work in the area of ballast tank coating research.

We then discussed who the proper people would be to meet with us at the Felling, United Kingdom facility. We discussed the need for process understanding and the need to develop a protocol for the test procedures in order to be able to validate the results and to insure that the paint companies would accept the results.

Tuesday May 19
Courtaulds Coatings
Stoneygate Lane
Felling, Gateshead
Tyne & Wear
United Kingdom

Met with the following:
Mr. Ian Thomas, Director of Marketing
Mr. Aidan Mernin, Chief Chemist Newbuilding
Mr. Michael Hindmarsh, Project Manager Newbuilding
Mr. Ian Royston, Chief Chemist Newbuilding
Mr. Eric Lynch, Principal Research Associate

An overview of the objectives of the project and the history of ACCI's involvement in the NSRP was presented. We discussed the measurement of thin dry film thickness (DFT) applied over a steel substrate with a blast cleaned profile. International stated that tank surfaces should be cleaned to a minimum SA 2½ (SSPC-SP 10) and that the pre-construction primer (PCP) be applied by automatic spray equipment to insure proper film morphology. International also recommended using a "Q" panel to measure dry film thickness with a target thickness of 16 µm, ± 3 µm (0.63 mils, ± 0.12 mils). We also discussed the relationship between the DFT and the substrate profile.

The possibility of using only one shop primer for the test program similar to the MARINTEK procedures were discussed. We also discussed the need to have one control panel tested along with the rest of the coatings. This control panel would have PCP applied and then completely removed. Salt contamination of the surfaces should be measured and be below 10 micrograms per square meter. International uses seawater, fresh water, and brackish water for PCP testing programs. ISO rust standards are utilized to evaluate PCP performance.

International recommends retaining the PCP after cleaning the welds, corrosion and physical damage. All visible contamination on intact primer for above water areas should be cleaned to Pt 2, with immersed areas cleaned to Pt 3. The stripe coat procedure should consist of a stripe coat, first coat, stripe coat, and then topcoat.

We discussed the degradation of coatings that are applied too thick. Process controls should be in place to prevent excessive DFT.

We discussed the need to simplify the paint schemes for the test program and to insure that the test program did not become a pre-qualification project.

Tuesday May 19
Ameron Protective Coatings Group
Geldermalsen, Netherlands
Met with the following:

Dr. Marten O. van der Meer, Vice President / Director
Mr. Bram van der Velden, General Sales Manager
Mr. Philip Constantinou, General Sales Manager Marine
Dr. Ko Keijman, Technical Director

Ameron reported that Germany was requiring the use of either 100 percent solids or waterborne coatings. This did not prove out in practice when we visited the German shipyard.

Dr.'s van der Meer and Keijman made a presentation on the history of PCP use in Europe. Just as in Japan, early PCPs consisted of zinc chromate pigmented polyvinyl butylral (PVB) materials. Russia is still using this type of material but is in the process of changing to some of the newer zinc filled silicate types. The Zaliv Shipyard is using Ameron 139 iron oxide epoxy primer, and the Nikolaev Shipyard is using a Russian PVB. Both these yards are in the Ukraine. Most other European shipyards were reported to be using the zinc filled ethyl silicate PCP. The Italian shipyards Monfalcone and Ancona are using Sigma Weld MC with Ameron "Bar-Rust 233H" topcoats in tanks. Ameron has documented successful service histories from these "Bar Rust" applications applied over Sigma PCP.

Ameron recommended that all cut edges be radiused to 2 millimeter for immersion service.

Ameron strongly recommended strip coating. The procedure should consist of application of the first coat to preserve the surface preparation followed by two stripe coats of contrasting colors followed by the application of the finish coat.

DR Keijman expressed some concern in the use of 100 percent solids epoxies applied directly over PCP. The performances of high solids epoxies are more dependent on mechanical adhesion and thus require a deeper surface profile or increased roughness. The PCP fills in the profile, which results in a smooth surface for the adhesion of the 100 percent solids material. He also expressed concern in the control of PCP thickness. He felt that there was a critical upper limit. The internal cohesive strength of the PCP is less than the epoxy topcoat. The thicker the PCP, the more pronounced the effect. Ameron's internal test program confirmed that PCP was a viable option provided thickness was controlled.

The discussion then centered on the relationship between the use of cathodic protection and the zinc filled PCP. Dr. Keijman stated that Ameron's experience was that the zinc filled PCP improved the performance of the coating system when used in conjunction with cathodic protection. This position was supported by both internal testing and service performance.

Wednesday May 20
Sigma Coatings
Amsterdam,
The Netherlands

Met with **Dr. Stephen E. J. Furtado,** Project Manager. Discussed the overall project objectives.

Sigma requires 40μm to 70 μm (1.6 mils to 2.8 mils) of surface profile with 20 μm (0.8 mils) minimum DFT of PCP. The preferred profile is 50 μm (2 mils). The acceptable thickness range is 18 to 25 μm (0.7 to 1 mil).

Sigma recommends either glass or polished steel panels to measure the DFT of an automated paint line. Tape is applied to the panel prior to PCP application. After the PCP is applied, the tape is removed and the difference between the bare area and primed area is measured using a double foot needle gauge. The difference is then taken to be the applied thickness. Sigma felt that with a good automatic application line that the thickness could be controlled to plus or minus 3 μm to 4 μm (0.1 to 0.2 mils).

We discussed the welding position performance in relation to the weld-through capabilities of the PCP. Sigma recommends less than 50 percent zinc by weight in the DFT. Secondary surface preparation can be with wire brush, 3M Scotch Brite ©, or grinders. Stripe coating is recommended using a stripe coating, first coat, stripe coat, and topcoat in contrasting light colors. All cut edges should be ground with a grinder. Even though Sigma recommends that the strip coat be applied after secondary surface preparation but before first coat application, it recognized that this might not always be practical.

Blasted and PCP primed steel is available from French steel companies. One of these companies is GTS. These companies are reported to retain the glass measurement plates as a part of the process control and quality documentation for audit.

Met with **Mr. Rodney H. Towers,** Market Development Manager, to discuss the use of epoxy coatings in ballast tanks. The subject of microbe attack on organic tank linings was discussed. Mr. Tower did not have any case histories of this phenomenon but did acknowledge that some components of the tank coating system could be a food source for some types of microbes.

Mr. Towers did not recommend the use of full thickness inorganic zinc coating systems in ballast tanks.

The classification societies are requiring hard, multi-coat, light colored tank linings with edge preparation in order to extend the inspection frequency. This has effectively discontinued the use of coal tar epoxy materials in Europe because of the dark color. The technique of edge preparation is not defined by the classification societies.

In order to apply the new PCP with higher solids and to solve the pot life issue, applicators are encouraged to invest in new variable ratio pumps.

Discussed that the uses of soft and semi-soft coatings are being phased out because of the inspection requirements. If soft coatings are applied, the regulatory and certification agencies require that the inspection interval be shortened resulting in an increase in frequency and thus cost.

Since some concern had been expressed at one of our NSRP SP-3 panel meetings about the performance of coating systems in the weld or burn heat affected zone when using PCP, this subject was discussed. Sigma stated that this had been a problem with some of the earlier organic based PCP’s but was not an apparent problem with the inorganic types. Most of the problems resulted from the heat deterioration of the organic binder. Where this was apparent (i.e., the coating had changed color) the defective material could be removed during secondary surface preparation. The real problem occurred when the degradation had occurred and was not visible. The topcoats were then applied over the defective, heat-damaged primer that could result in premature failure.

Met with the following:
Mr. Maarten van Scherpenzeel, Managing Director
Mr. Graham D. Rolph, General Sales Director

We discussed overall objectives of the research project and the history of the NSRP and ACCI's involvement in the ballast tank coatings.

Wednesday May 20
YVC Ysselverf B.V.
IJsseldijk 97
IJssel, Holland

We traveled with **Dr. Furtado** to the above shipyard and met with **Mr. Piet. Alblas EWE**, YVC Ysselverf B.V**.,** and **Mr. Gert-Jan Nederveen** Sigma Paint. We discussed the involvement of Sigma Paint in the NSRP project, the history of the NSRP, and the value of the retaining PCP. We discussed the value of preparation of cut steel edges. Mr. Alblas felt that edge preparation was very important. The Ysselverf shipyard is presently working to develop a tool that can radius both sides of cut edges at one time. At present, the yard is radiusing all cut edges using flexible pad sanding discs. Secondary surface preparation for interior tanks and underwater immersion areas consists of sweep blasting using recyclable garnet abrasive.

Mr. Alblas reported that the PCP used in the shipyard has very little burn through. YVC Ysselverf B.V. shipyard buys all steel primed with a specified PCP. We toured the shipyard and observed very good process control both in the coatings application and the steel construction.

This shipyard purchases all plate with Sigma Weld MC PCP from France.

Friday May 22
Howaldswerke-Deutsche Werft AG
Kiel, Germany

We met with **Mr. August Nitschmann**, of Corrosion Protection. Howaldswerke-Deutsche Werft AG (HDW) presently builds a wide variety of commercial ships and military ships including submarines. Eighty percent of the work is commercial. The present work force is approximately 3,500 workers with 500 to 1,000 sub-contract workers. Military frigates are built to merchant standards. HDW is very aware of the correlation between service life and cost of construction, and provides customers with cost/service life options.

Steel is blasted to SA 2½ with a 40µm to 60µm profile (1.6 mils to 2.4 mils) with PCP applied 15µm to 20µm DFT (0.59 mils to 0.79 mils). Dry film thickness is controlled using the glass plate technique. As an example, one PCP thickness record noted an average thickness of 16.2 µm, a minimum of 11.9 µm, a maximum of 19.7 µm with a standard deviation of 2.3 µm.

In the past, PCP was either not applied to, or was completely removed from steel destined for Naval vessels. PCP is presently being retained for the new Navy frigate program, including tank and immersion areas.

HDW uses only S-280 steel shot in the automatic blast machine in the plate line. Uncontained exterior secondary surface preparation blasting is performed using copper slag abrasive. Most secondary surface preparation for tanks is being done inside large, environmentally controlled blast and paint halls using recycled steel grit.

Hempel 3550-epoxy tank coating is being routinely applied over the Sigma Weld MC PCP. Sixty to eighty percent of all ballast tank coatings are applied in the large paint halls. The coating system consists of an epoxy holding primer plus the standard high performance epoxy tank coating. HDW prefers one coat of 400µm (15.7 mils) for the top coat. Owners sometimes request two coats of 200µm (7.8 mils) to insure that there are no holidays. One stripe coat is always applied before the topcoat. Edges are broken on all navy vessels. Edges are not broken on a commercial vessel unless defined so as a part of the contract.

Inorganic zinc coatings are not used in ballast tanks. The German Navy has experienced problems with some epoxy coating systems in fuel oil compensating tanks, but uses the same system in these areas as the one used in ballast tanks.

HDW has developed internal construction standards, including coating standards and does not rely on the test results from MARINTEK to qualify a system.

Primer is not always welded through, especially when submerged arc welding (SAW) is used.

Secondary surface preparation for exterior surfaces and tanks consists of blasting all welds, physical damage, and burn marks to SA 2½, the remaining PCP is cleaned to SA 2½, using sweep blasting. Sweep blasting is accomplished in the shop whenever possible.

Waterjetting is not used by HDW because moisture added to steel surfaces is difficult to remove in the northern European climate.

HDW has used shop primers since 1959.

Zinc anodes are not installed in ballast tanks on new commercial ships.

Anodes are installed in naval vessel ballast tanks.

The German Ship Association (Schiffbautechnische Gesellschaft e.v.) has developed many shipbuilding standards for use in the German shipbuilding community, including a visual standard for waterjetting. STC Guidelines Number 2215 dated 2 August 1987 is the title of the standard. This organization is located at Lammersieth 72, 22305 Hamburg. The excellent visual waterblast standard is Standard Guide 2222. DIN 55928 is a nine part German shipbuilding coatings standard. The connection between the German Ship Association standards and DIN is clear.

We were given a tour of the yard, concentrating on the coating and welding operations. During the tour of the blast and primer line, we found that HDW is using statistical process control to monitor the output of the paint line. During each shift, DFT readings are recorded into a computer and the average, high, low, and standard deviation then determined and recorded. DFT readings are taken of smooth steel plates approximately 1m by 100 mm (3.3 feet by 3.9 inch), that are passed through the paint line. We were shown the very large blast and paint halls where large construction blocks are brought prior to assembly in the dry docks. All of the secondary surface preparation and finish coating, with the exception of future construction seams, are completed in these halls. The paint shops were very orderly, with the majority of the coatings being supplied to the yard in totes. A tour of the welding area included extensive use of robotic welders. An interesting feature of the robotic panel line is the incorporation of a small abrasive blaster that removed the PCP in the areas of large fillet welds. All of the cut steel pieces had accuracy control (AC) markings.

Tuesday May 26
Hempel
Lyngby, Denmark

We met with the following:
Mr. Knud Strange Nielsen, Manager
Dr. Ole Borring Sorensen, Marketing Department
Mr. Erik Mikkelsen, Technical Service Department

Mr. Nielsen gave an overview of the history and current status of the Hempel Company. Hempel recommends a zinc silicate PCP applied no thicker than 15µm (0.6 mils) for automated cutting lines, especially when lasers are used. Organic PCP's are not recommended because of the negative affect on welding. Hempel supplies Swedish Steel Company with the PCP applied to its blasted steel plates, which is then supplied to many of the shipyards in Northern Europe. The Swedish company supplies 500,000 tons per year of PCP primed plate and structure. The line was reported to run at eight meters per minute. There are two primary primer suppliers to the Swedish company, Jotun and Hempel.

Hempel recommends that DFT measurements for PCP be taken on smooth steel strips in the same manner as found at HDW shipyard. This technique consists of attaching the smooth strip to the plate being primed, after the plate has exited from the blast machine. The smooth strip is 3 millimeter thick, 1m wide by 100 mm long (3.3 feet by 3.9 inch). The length is selected to account for all overlap spray pattern areas. A fixed probe magnetic gauge is calibrated over the smooth, uncoated plate using certified plastic shims. After the PCP is applied the thickness is measured and recorded using the same gauge. Film formation is verified visually using a glass plate. Film thickness verification is much more difficult for shapes (profiles). The line is essentially set up to run plate and then used to coat shapes.

Hempel has performed in-house testing and found that using the RUGOTEST (Rz - value) for measuring substrate profile is the most accurate. The test involves taking the average value of the absolute values of heights of five maximum profile peaks and the depths of five maximum profile valleys.

In order to insure the proper film morphology and to insure that all water has been removed, Hempel recommends that the temperature of the steel substrate be at 30° C (86° F).

Wherever possible, Hempel supplies coatings in 1000-liter (264-gallon) totes.

Hempel has agreements with other coatings manufacturers to supply topcoats that can be applied over the others' PCP. Hempel provides PCP in three different colors for material control.

Hempel has found that film thicknesses greater that 25µm (1 mil) can effect the cohesive strength of the PCP.

Hempel recommends that secondary surface preparation for ballast tanks consist of blasting of weld to SA 2 ½ plus sweep blasting of the PCP. A heavy sweep was defined as 15 to 20 square meters per hour, and a light sweep as 35 square meters per hour. G 25 steel grit was the preferred blast media. No test was performed for surface contamination in the paint hall prior to coatings application.

Hempel recommends that all cut edges be rounded.

For epoxy top coating, Hempel recommends a minimum 200 µm (7.8 mils) to ensure corrosion protection. Hempel related that experience had shown that fifty percent of all repairs during the first five years were due to the application of single coat ballast tank coating systems. One explanation was that holidays and pinholes were more prevalent in the one coat system due to applicator error. Seventy percent of all ballast tank coatings are now light colored. This is due to the pressures of the certification societies.

Hempel has developed a database that allows tracking of the performance of coatings.

We were given a tour of the laboratory where various coatings are tested. Hempel performs in-house testing of all candidate-coating systems prior to submittal to MARINTEK for conformation testing. Hempel's opinion was that in-house testing would result in the same findings as MARINTEK although Hempel's testing does not include testing with tanks that oscillate.

We were given a tour of the Hempel paint factory

Wednesday May 27
Odense Steel Shipyard Ltd.
Odense C. Denmark

We met with **Mr. Glenn Frank**, Technical Paint Manager. Odense Shipyard applies PCP at 15µm, ± 5 µm (0.59 mils, ± 0.20 mils) on steel that has been cleaned to SA 2½. MG 18 steel grit is reported to be used in the automatic blast machine, but samples of the abrasive appeared to be smaller than MG 18 and were somewhat rounded through use. Odense always measures the steel profile using a comparator. The PCP is measured using a smooth steel strip.

Odense uses 75 percent zinc PCP.

Secondary surface preparation in the paint halls consisted of abrasive blasting of all welds and damaged areas to SA 2 ½ using G 24 steel grit. Secondary surface preparation on the ways consisted of power tool cleaning to St3 using sanding discs.

Where possible, tank coatings are applied in the large paint halls. Future weld areas are blasted but left bare. Ballast tanks are coated with three stripe coats and three top coats with alternating cream and red colors starting with a red stripe coat over the prepared PCP. All cut edges in ballast tanks are radiused with a power tool using a sandpaper wheel. Odense uses a PCP color that facilitates recognition of areas where the secondary surface preparation has been accomplished.

Odense uses approximately 1.5 million liters (396,000 gallons) of coating per year. Virtually all of the coatings are received in totes. Holiday detection is done by taking a statistically significant sample and is not done over 100 percent of the surface.

Zinc anodes are installed in all new ballast tanks.

Thursday May 28
Jotun Paints
Sandefjord, Norway

We met with **Mr. Ragnar Jahr**, Sales Director Marine Coatings. Mr. Jahr gave a history of Jotun and a tour of the Jotun museum. We were joined by:
Mr. Gunnar B Gustavsen, Manager Newbuilding Department
Mr. Jan Nygard, Section Manager, R & D

We discussed the performance of ballast tank coatings with or without anodes.

Jotun is using magnesium descaling to successfully descale rusting in ballast tanks. Magnesium anodes are installed before the last voyage prior to dry-docking. By the time the ship is dry-docked, the rust scale has all fallen to the bottom of the tank and after removal, the tank can be waterjetted and a surface tolerant coating applied.

We were shown a dramatic video entitled "Sinking Standards" which showed the results of corrosion going unchecked in ballast tanks, resulting in the sinking of the vessel. Jotun believes that the life of a vessel depends on increasing the thickness of the steel, application of coatings in accordance with current standards, and the use of anodes to monitor the performance of the coating. A twenty-five year life for a vessel is possible with the coating system accounting for ten years, the steel thickness accounting for ten years, and the cathodic protection accounting for five years. It is estimated that twenty percent of the world's shipping fleet is in poor condition.

Jotun recommended that the profile of the steel substrate be between 40µm to 90µm (1.6 mils to 3.5 mils) measured with a comparator. Jotun recommended that the PCP be applied at 15µm to 20µm (0.6 mils to 0.7 mils). Jotun reported that smooth steel plates should be used for the measurement of DFT with at least eighty-five percent of the reading being within 3µm (0.1 mils) of the specified DFT.

For secondary surface preparation, Jotun recommends that welds and physical damage be cleaned to SA 2½. The remaining areas of PCP are sweep blasted. Tools used for secondary surface preparation are grinders with sanding discs, 3M Scotch Brite © clean and strip pads, and needle guns. Cut edges are radiused to a 2 mm (.08 in) using a three step procedure. If a surface tolerant coating is to be used as a topcoat, waterjetting is preferred to clean the PCP. After the secondary surface preparation, Jotun recommends a stripe coat applied by brush, a top coat applied at 150µm (5.9 mils), a second stripe coat applied by brush, and the final top coat applied at 150µm (5.9 mils) followed by the installation of anodes. Jotun recommends anode protection of 5 milliamp per square meter to provide protection for a ten-year system.

We were given a tour of the Jotun test laboratory where extensive in-house testing is accomplished to pre-qualify coatings prior to sending them to MARINTEK for approval.

Friday May 29
MARINTEK
Norwegian Marine Technology Research Institute
Sandefjord, Norway

We met with:

Mr. Tore Wood, Research Manager
Mr. Helge Vold, Senior Research Engineer

Mr. Wood gave an overview of the testing that MARINTEK performs for the marine industry. MARINTEK has developed a unique test for ballast tanks where the tanks oscillate to simulate the movement of water in a ballast tank while a vessel is underway. The ballast tanks are filled and emptied on a three-week schedule, two weeks filled with water, one week empty. Water is taken from the nearby fjord. MARINTEK concentrates on laboratory testing rather than field-testing because tests in the field are more expensive and are not repeatable. **Mr. Vold** reported that the steel for the ballast tank tests are blasted to SA 2½ then one coat of PCP is applied by hand. A stripe coat is then applied followed by a topcoat, another stripe coat, and then the final topcoat.

A tour of the testing facility was given. All of the coatings tested are given a rating based on their test performance.

Additional observations at MARINTEK included:

- PCP was applied by hand in all cases. The understanding was that if all were applied by hand the tests would be normalized.

- Initially all of the ballast tank coatings were applied over PCP supplied by one company.

- Each coating manufacturer does pre-screening prior to submittal to MARINTEK using internally developed test sequences.

- Coating performance, except for the classification, is proprietary.

- Ballast tank coatings are tested in specially designed tanks on a three week ballast schedule: two weeks half full, one week empty

- MARINTEK researchers felt the Bresle test for chloride was not reliable.

APPENDIX B

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APPENDIX B
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Gilbert, M. Scott	Advances in Chemical Tanklining	Proceedings of the SSPC 1996 Seminars, Charlotte, NC	Nov-96		pp. 262-269
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Armstrong Ken R.	Dehumidification for Enclosed Spaces During Surface Preparation and Coatings Operations	Proceedings of the SSPC 1997 Seminars, San Diego, CA	Nov-97		pp. 87-92
Ayers, Charlie	Electrolytic Descaling of Water Ballast Tanks of Ships	Proceedings of the SSPC 1997 Seminars, San Diego, CA	Nov-97		pp. 325-326
Bauer, Mike	Organic Zinc-Rich Primer for the Interior and Exterior of Potable Water Tanks	Proceedings of the SSPC 1997 Seminars, San Diego, CA	Nov-97		pp. 81-86
Bowry, Earl V.	User Friendly, Multi-functional Solvent Free Epoxies	Proceedings of the SSPC 1997 Seminars, San Diego, CA	Nov-97		pp. 72-75
Buesig, Kirby	Field Problems with High Solids Products	Proceedings of the SSPC 1997 Seminars, San Diego, CA	Nov-97		pp. 55-57
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Gilbert, Scott M.	Avoiding Common Pitfalls of New Construction: Full Shop-Applied Vs. Field-Finish	Proceedings of the SSPC 1997 Seminars, San Diego, CA	Nov-97		pp. 231-237
McCarthy, James	New Topcoating Technology for Maintenance of Marine and Offshore Structures	Proceedings of the SSPC 1997 Seminars, San Diego, CA	Nov-97		pp. 327-330
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Dillon, C. P.	Some Considerations in the Economics of Tanker Corrosion	NACE Publication 3H156			
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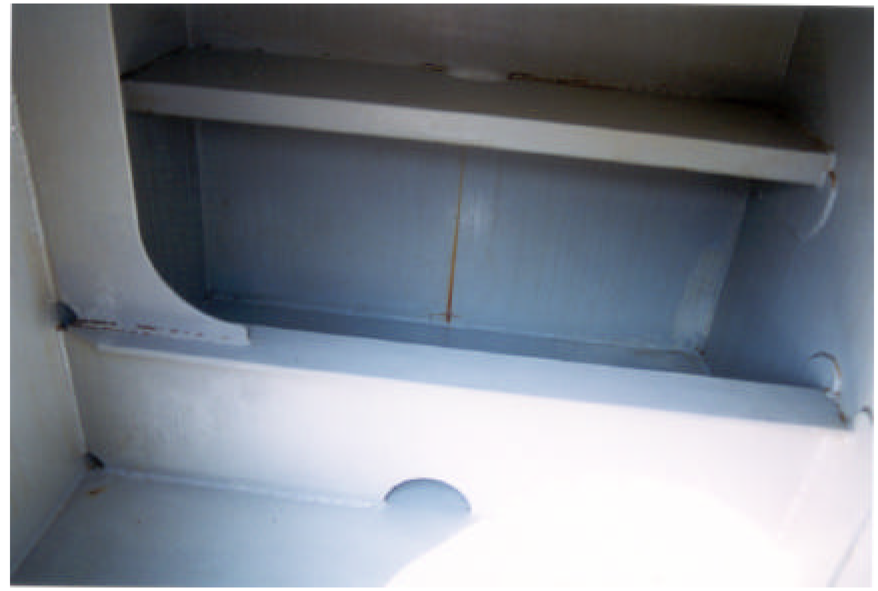
	Coating Requirements of Ballast Tanks	Norwegian Maritime Directorate			

APPENDIX C

Tank Photographs



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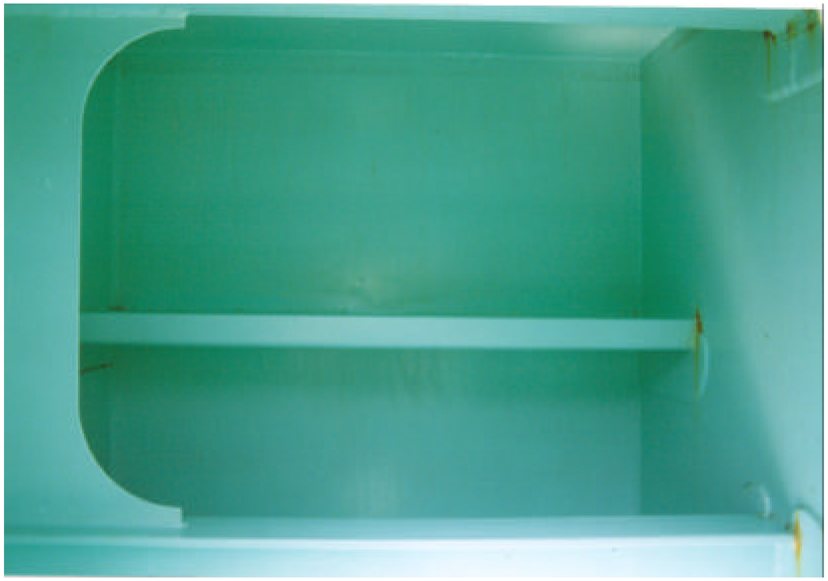
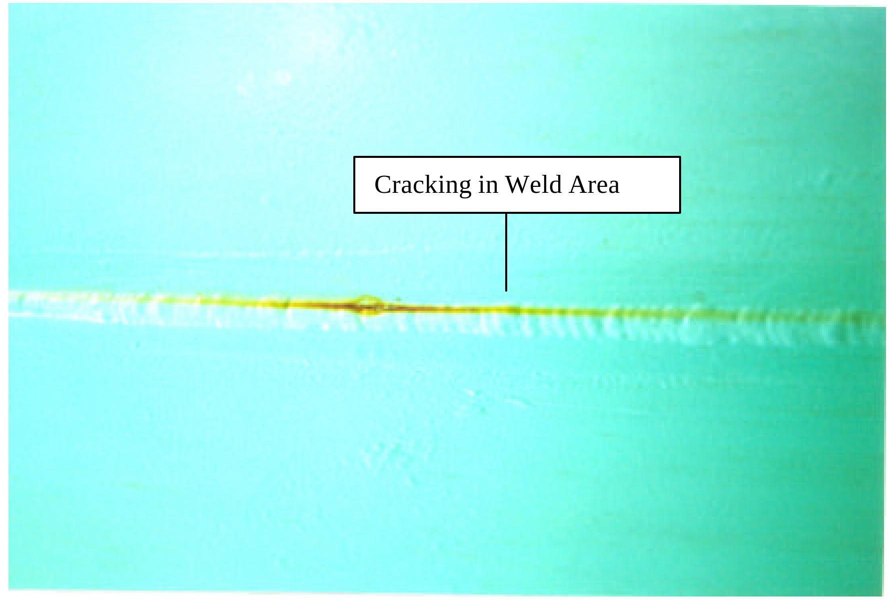


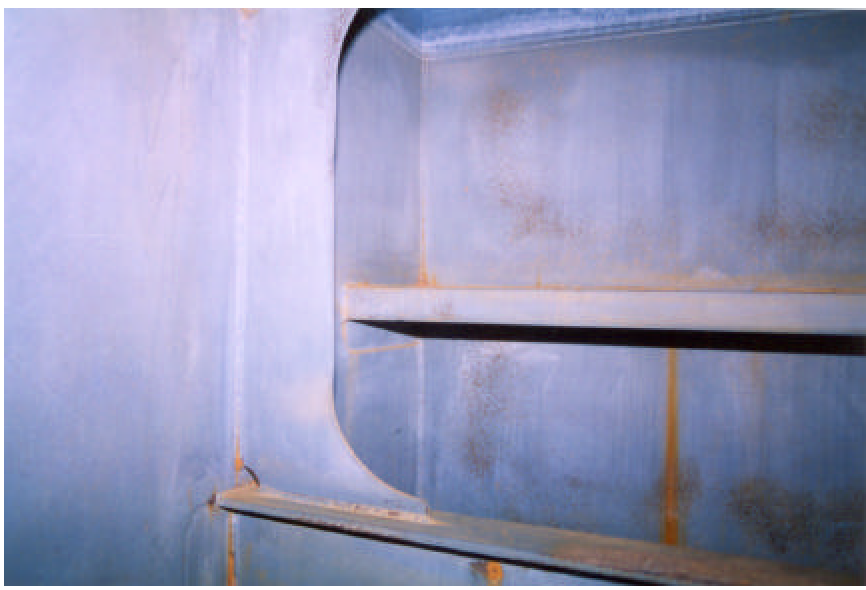


Tank A-2

Tank A-3


Tank B-1


Tank B-2



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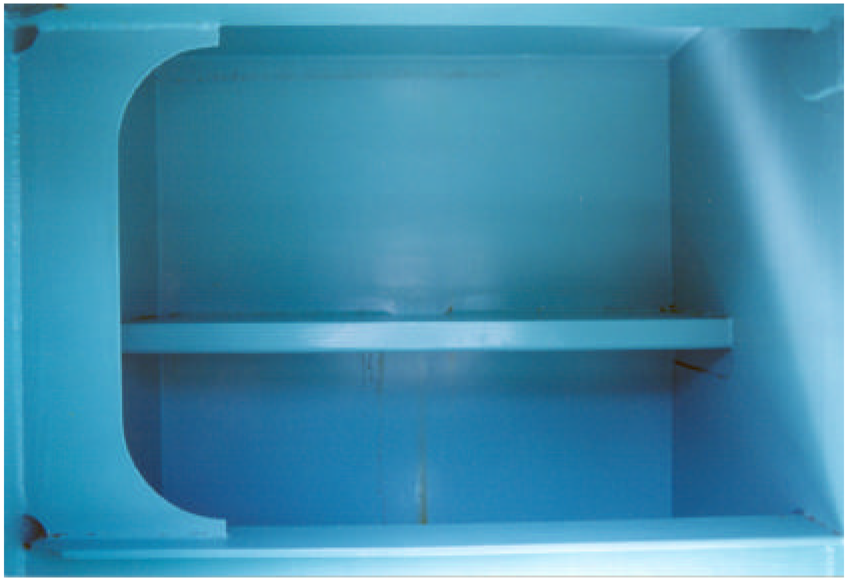

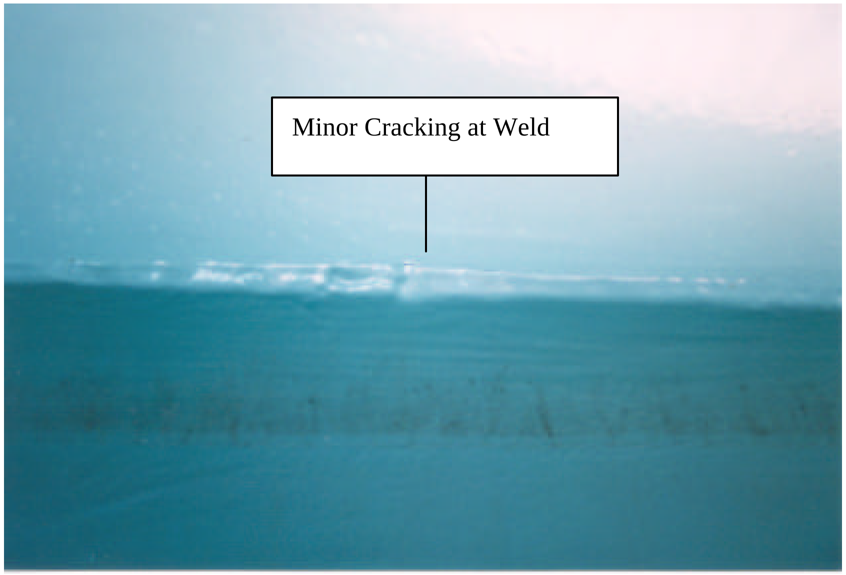

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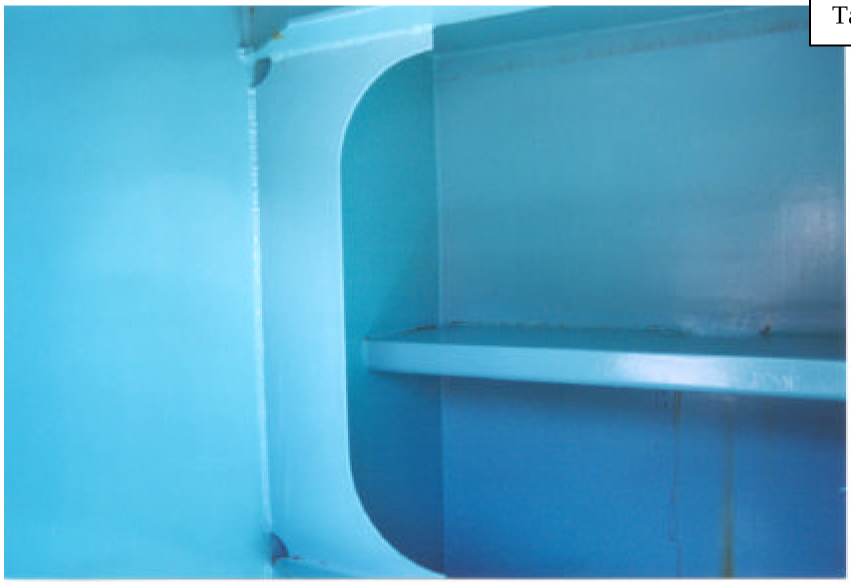

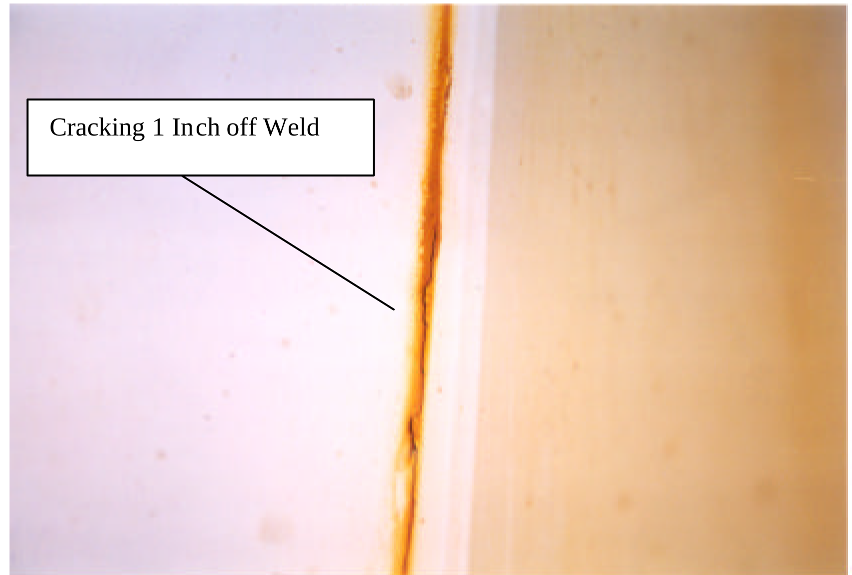

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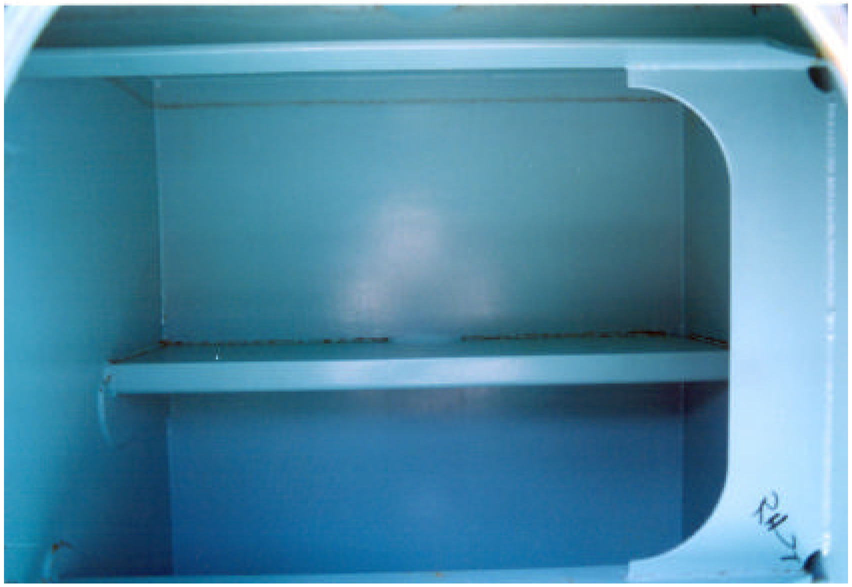
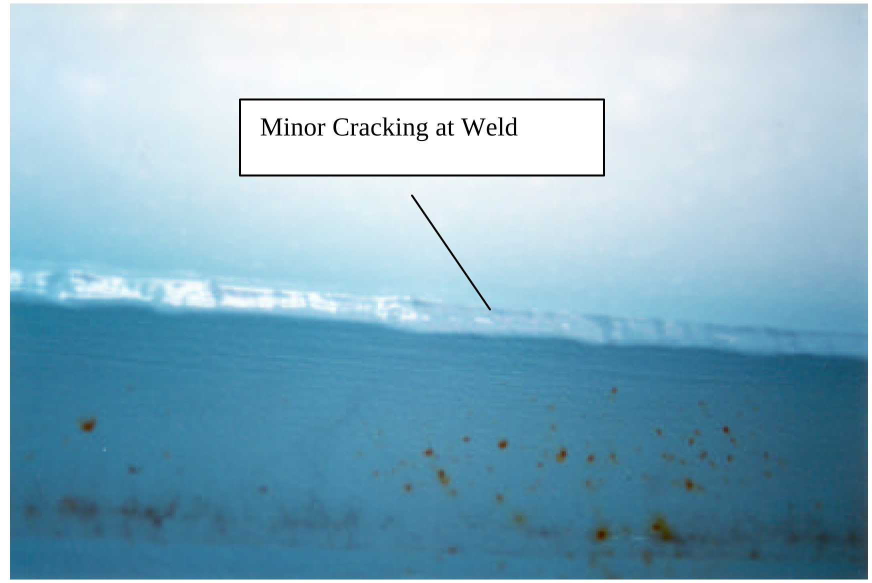
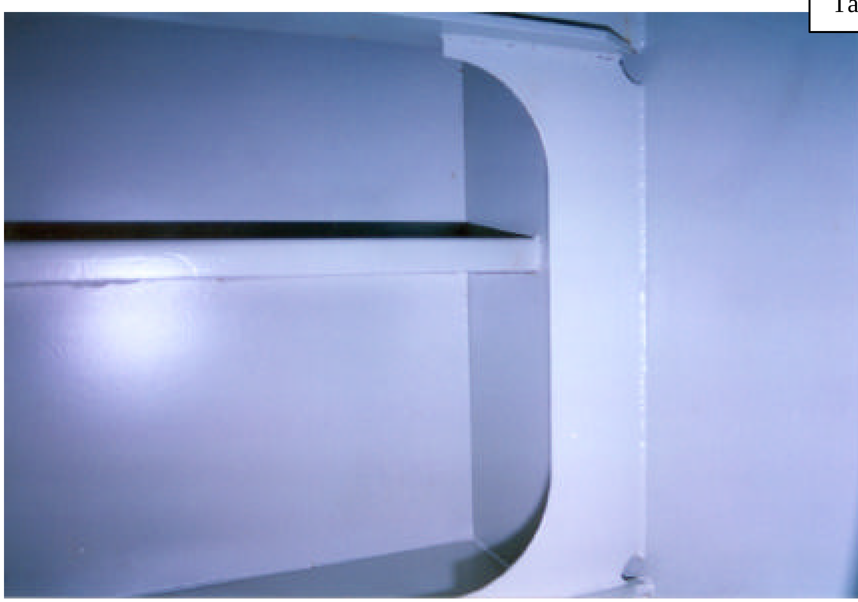




Tank C-3

Tank D-1

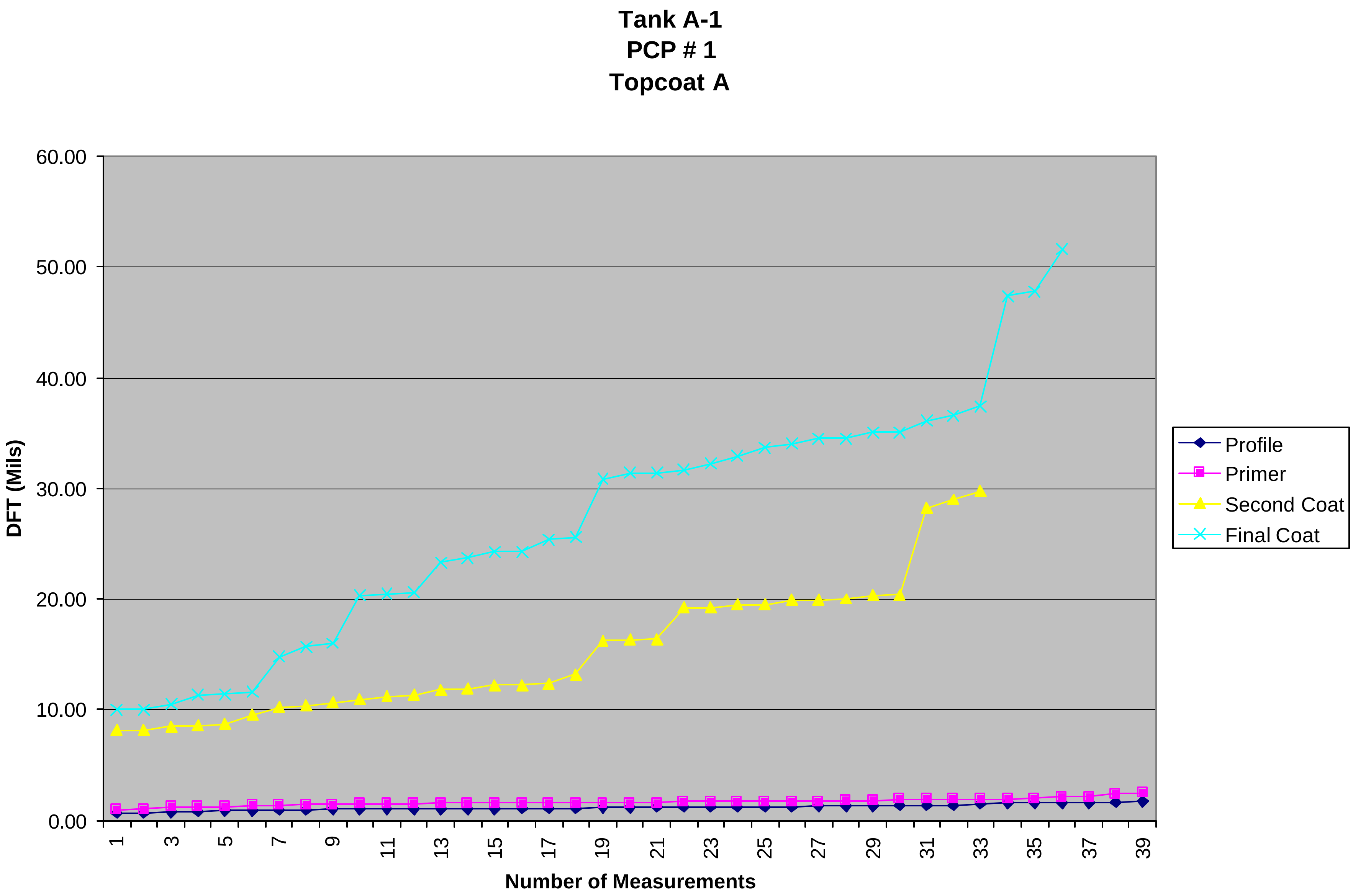


Tank D-2

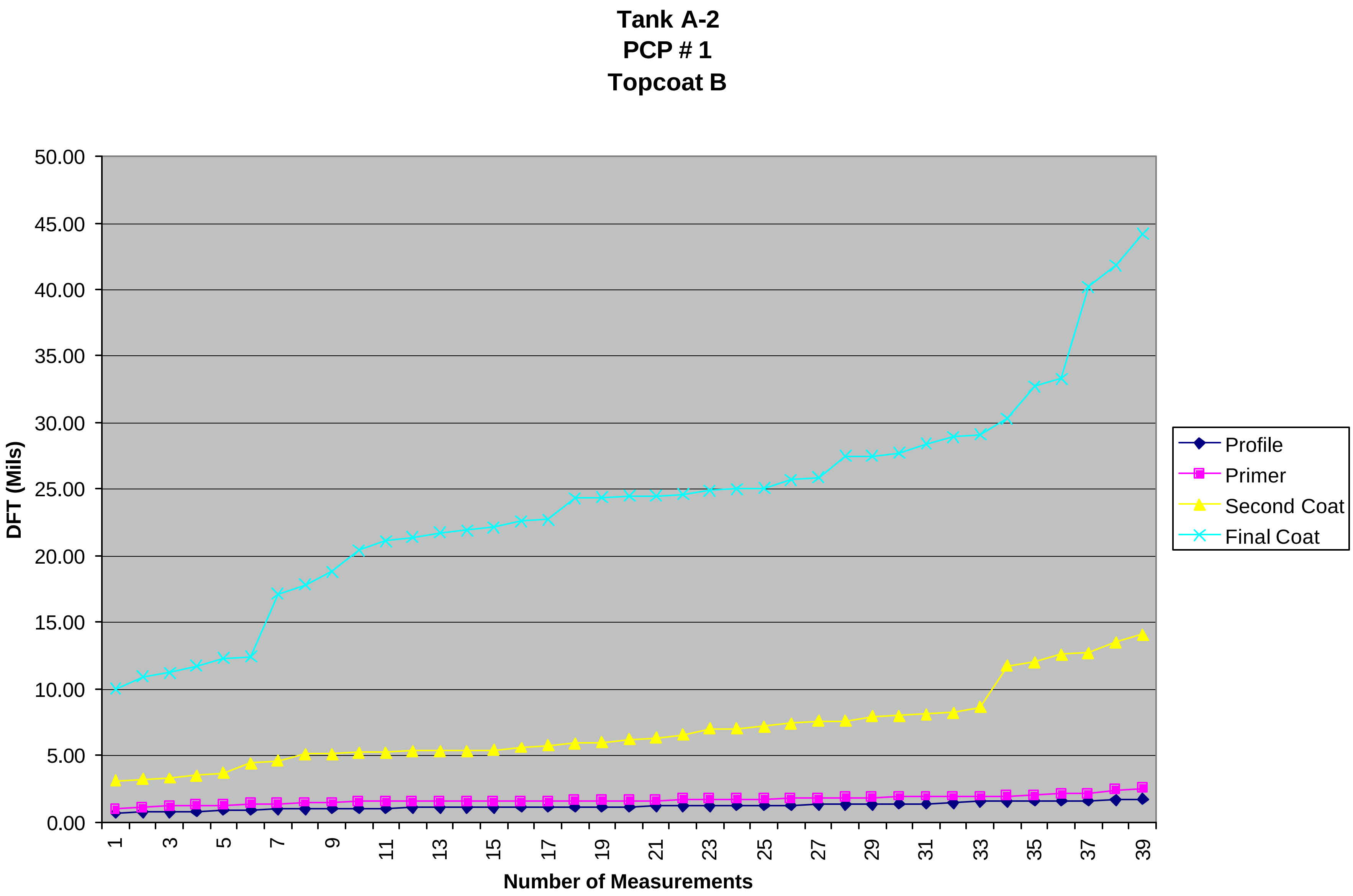
Tank D-3

Appendix D

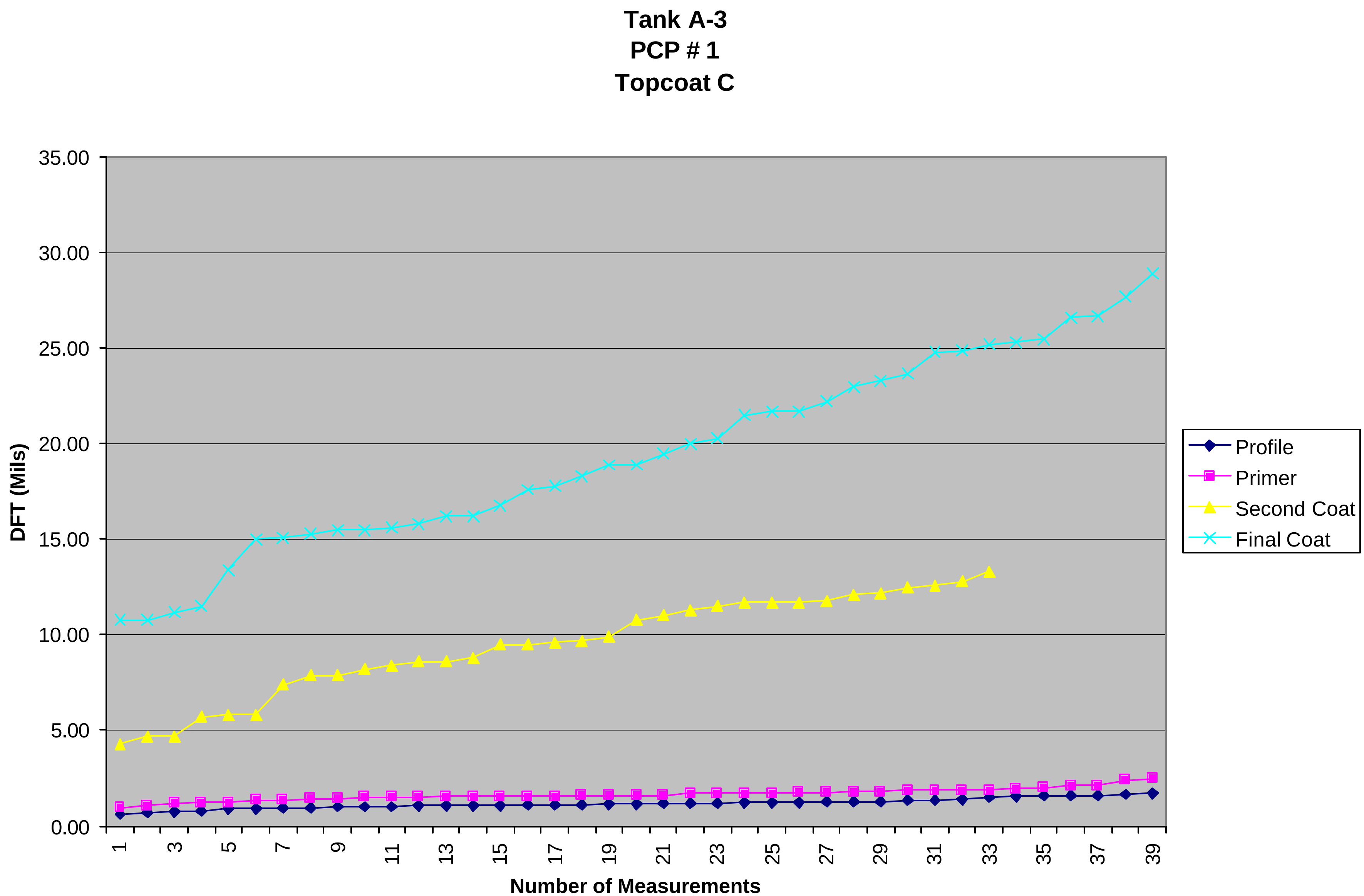
Dry Film Thickness Grafts

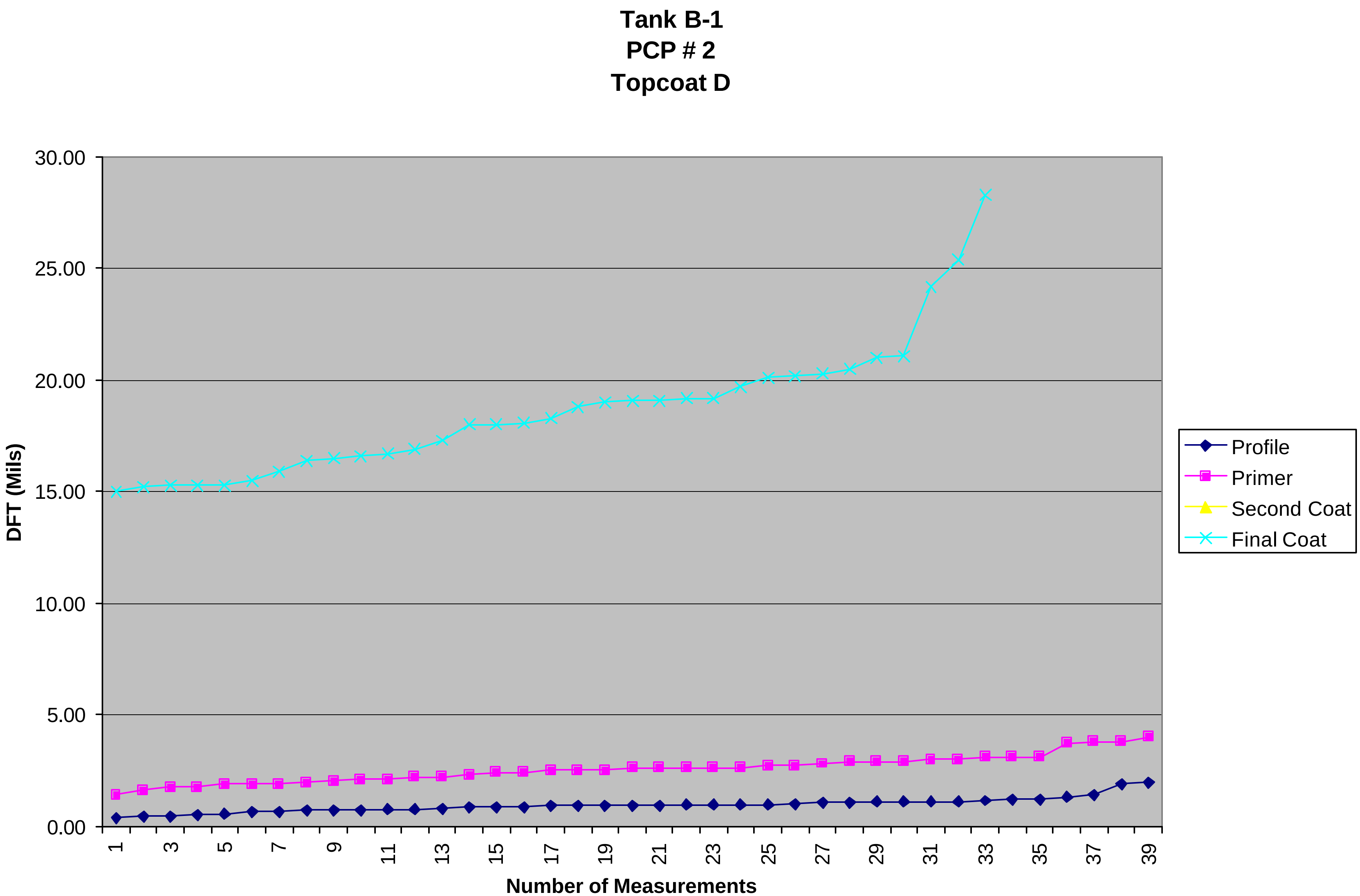


Tank A-1
PCP # 1
Topcoat A
DFT (Mils)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
Number of Measurements
Profile
Primer
Second Coat
Final Coat



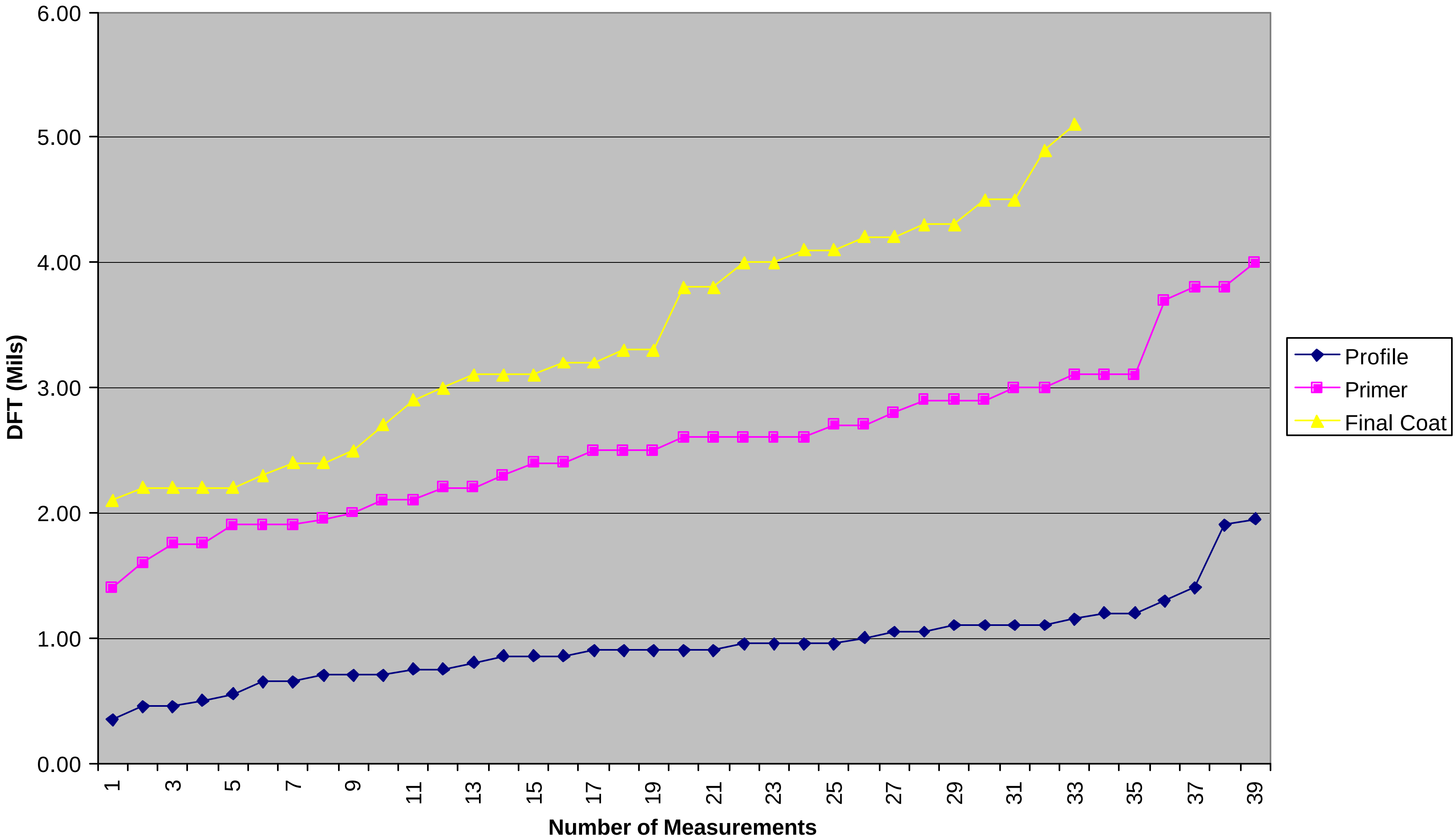
Tank A-2
PCP # 1
Topcoat B
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
DFT (Mils)
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
Number of Measurements
Profile
Primer
Second Coat
Final Coat

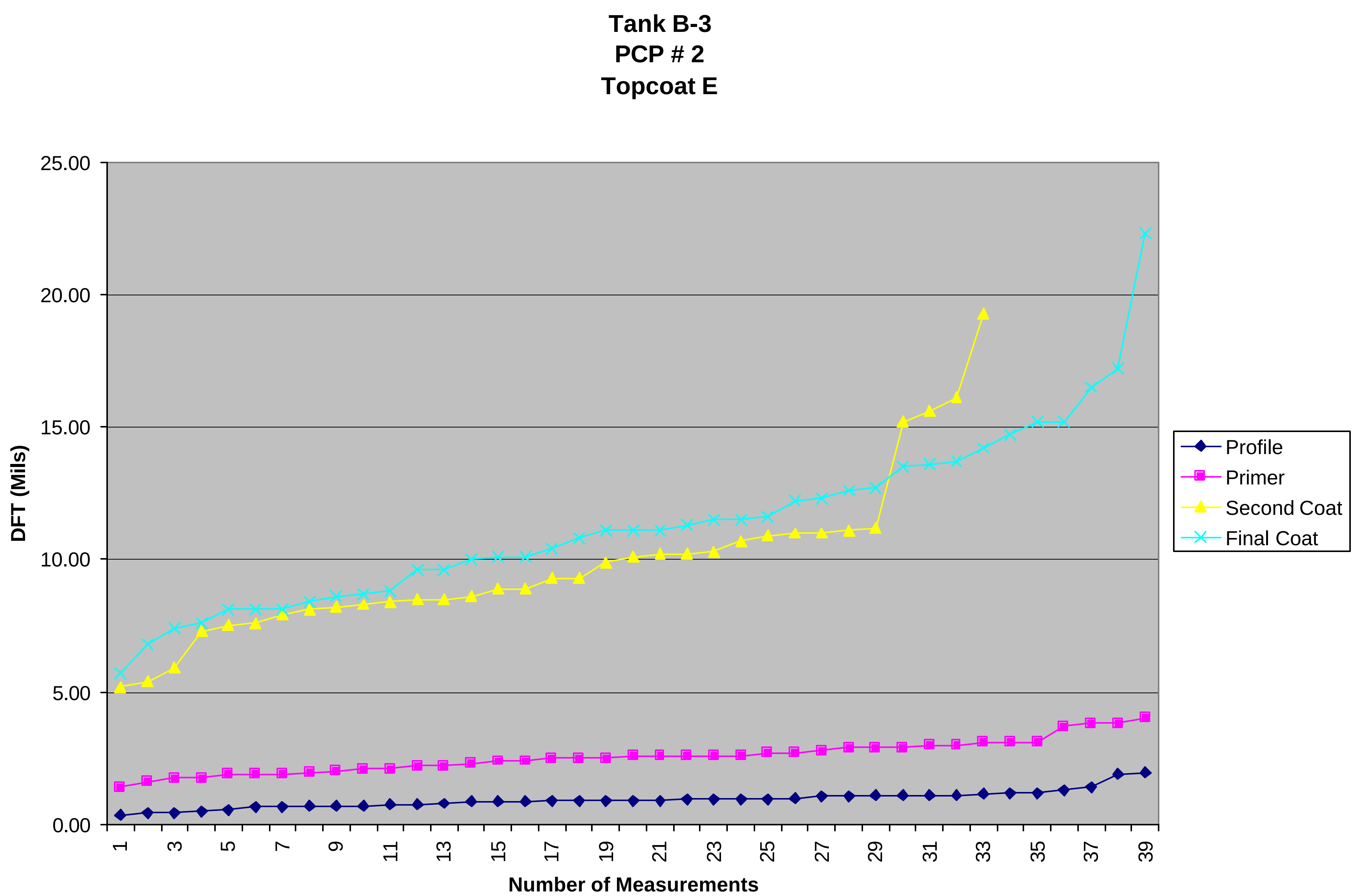

Tank A-3
PCP # 1
Topcoat C
DFT (Mils)
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
Number of Measurements
Profile
Primer
Second Coat
Final Coat



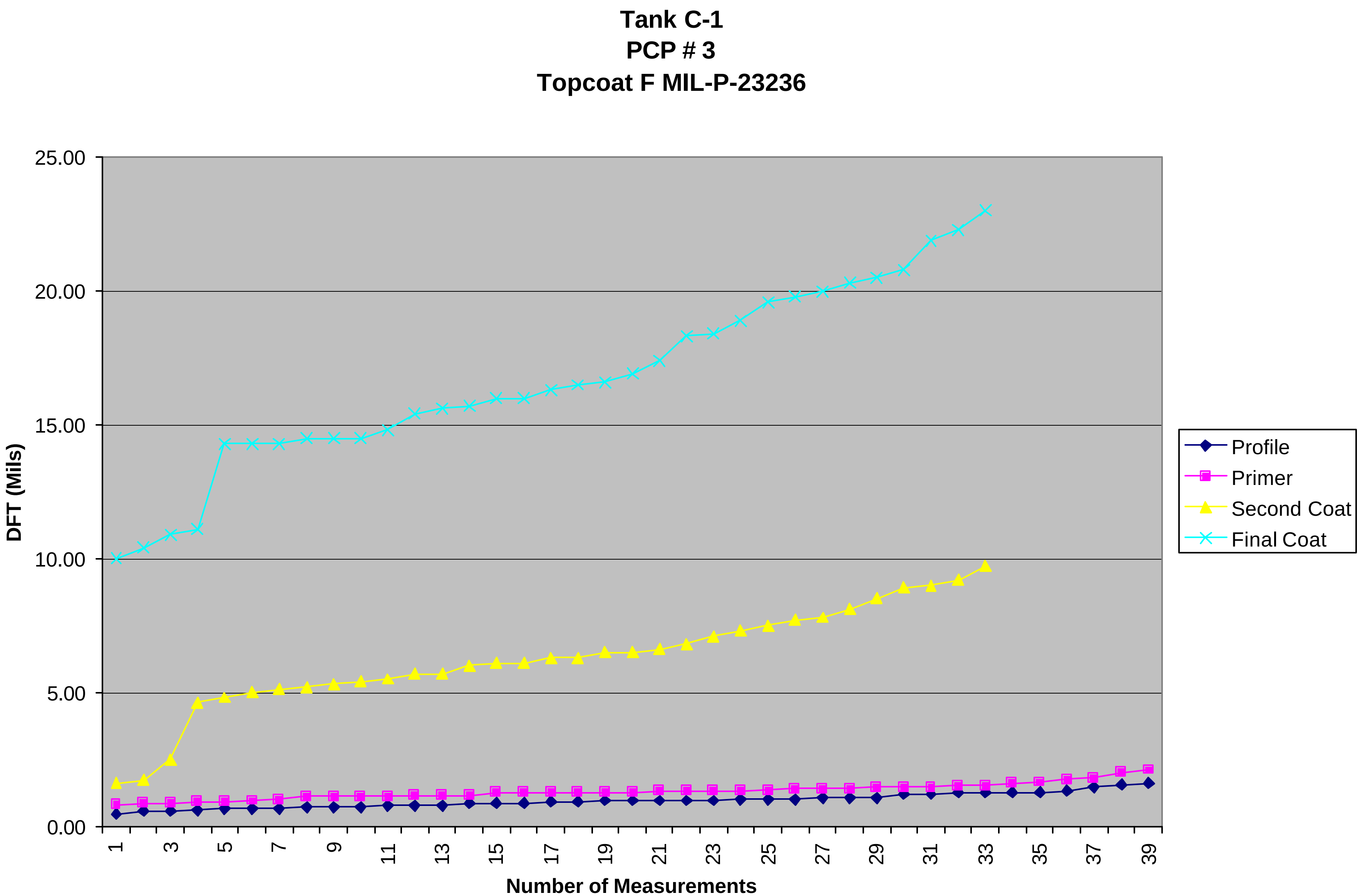
Tank B-1
PCP # 2
Topcoat D
DFT (Mils)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
Number of Measurements
Profile
Primer
Second Coat
Final Coat

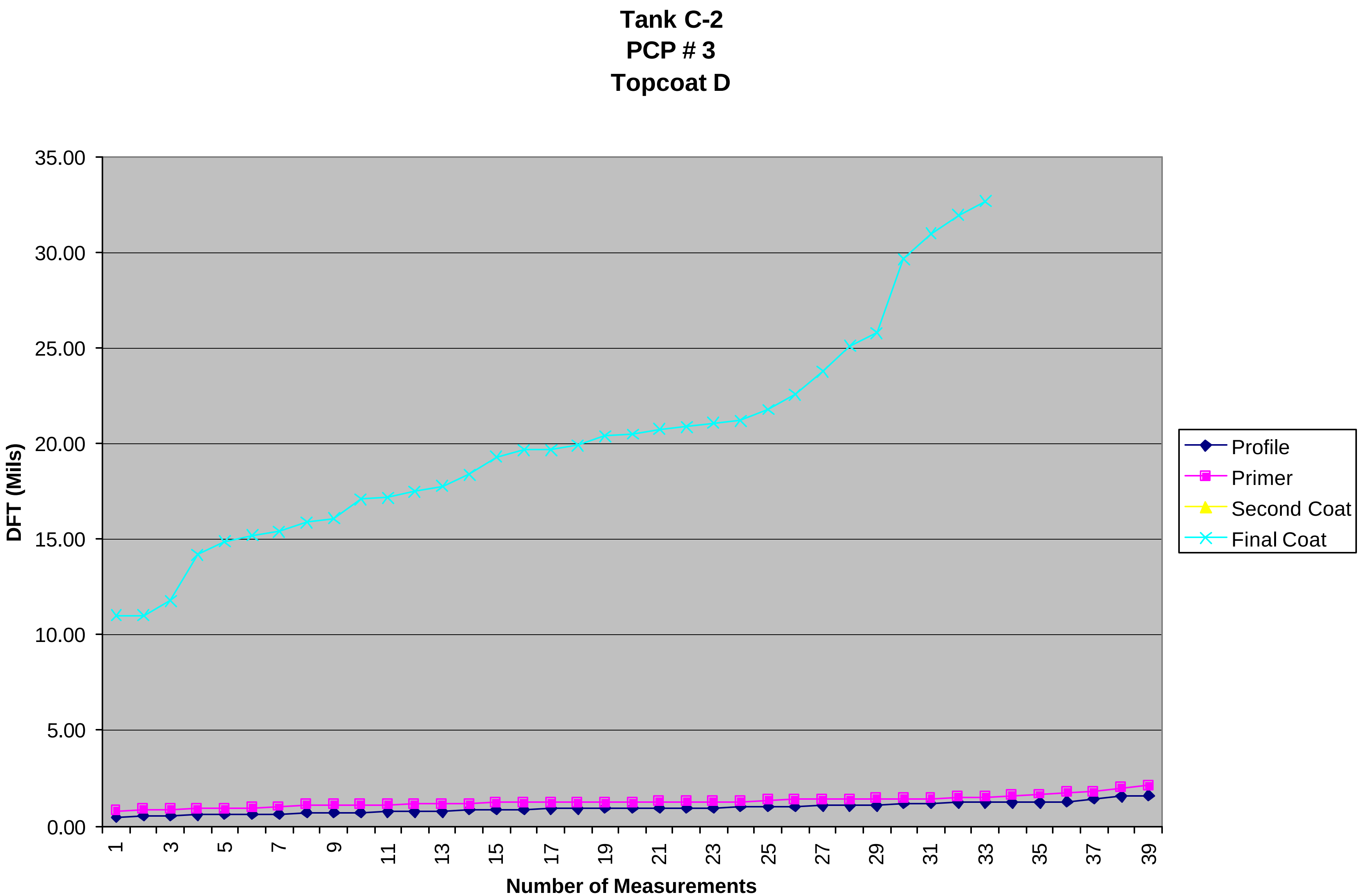
Tank B-2
PCP # 2 Inorganic Zinc Topcoat

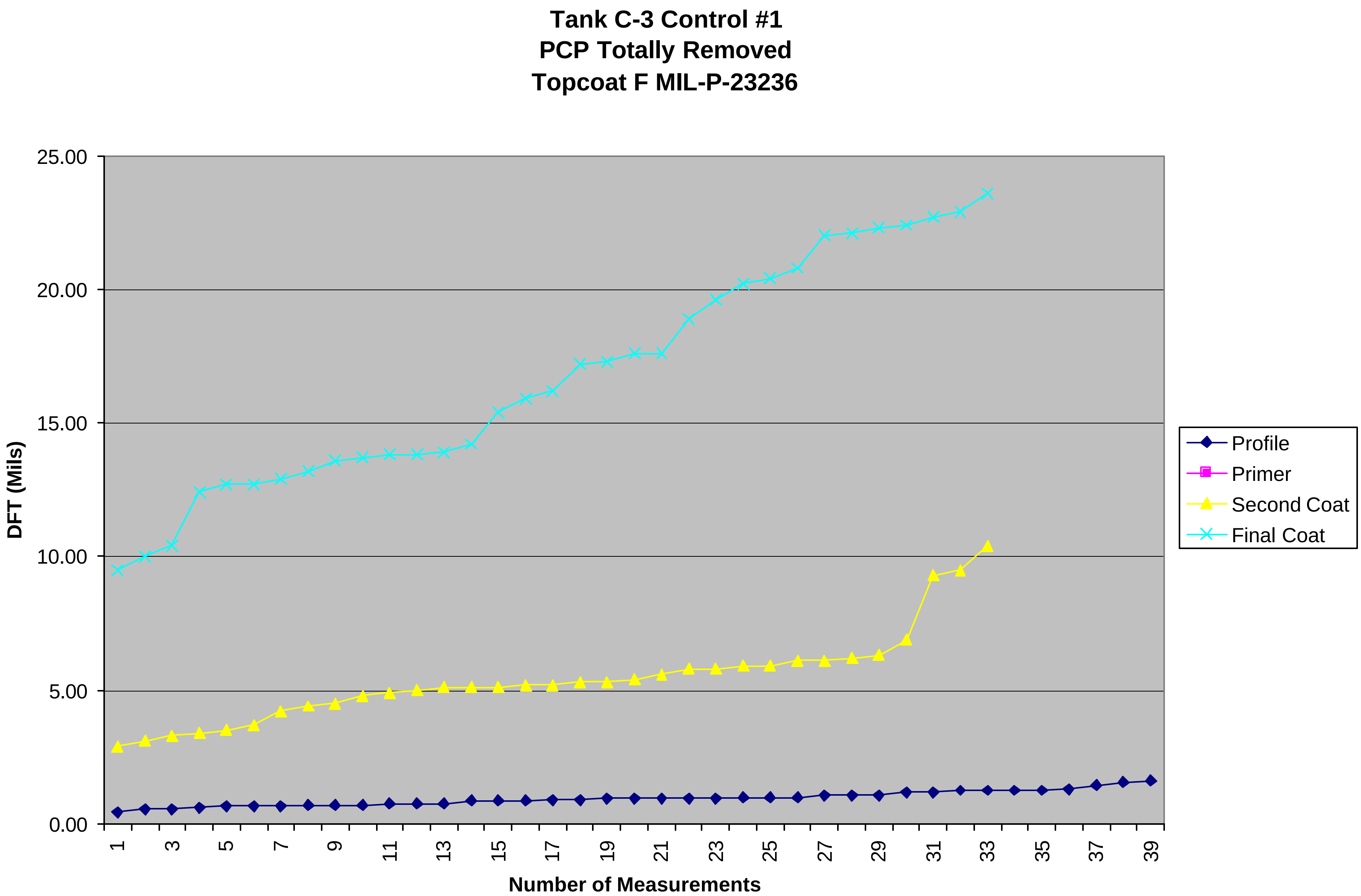


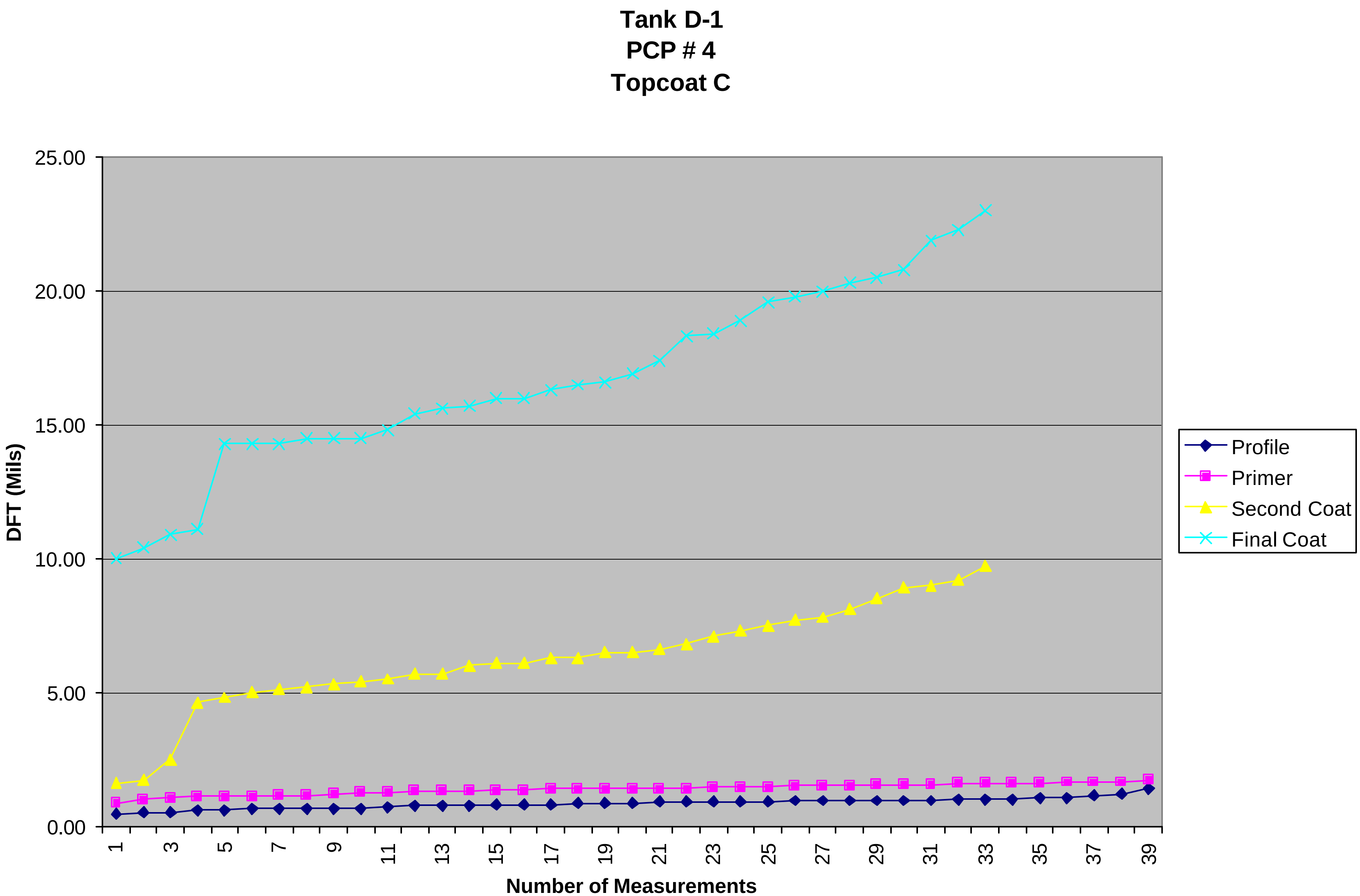


Tank B-3
PCP # 2
Topcoat E
DFT (Mils)
25.00
20.00
15.00
10.00
5.00
0.00
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
Number of Measurements
Profile
Primer
Second Coat
Final Coat

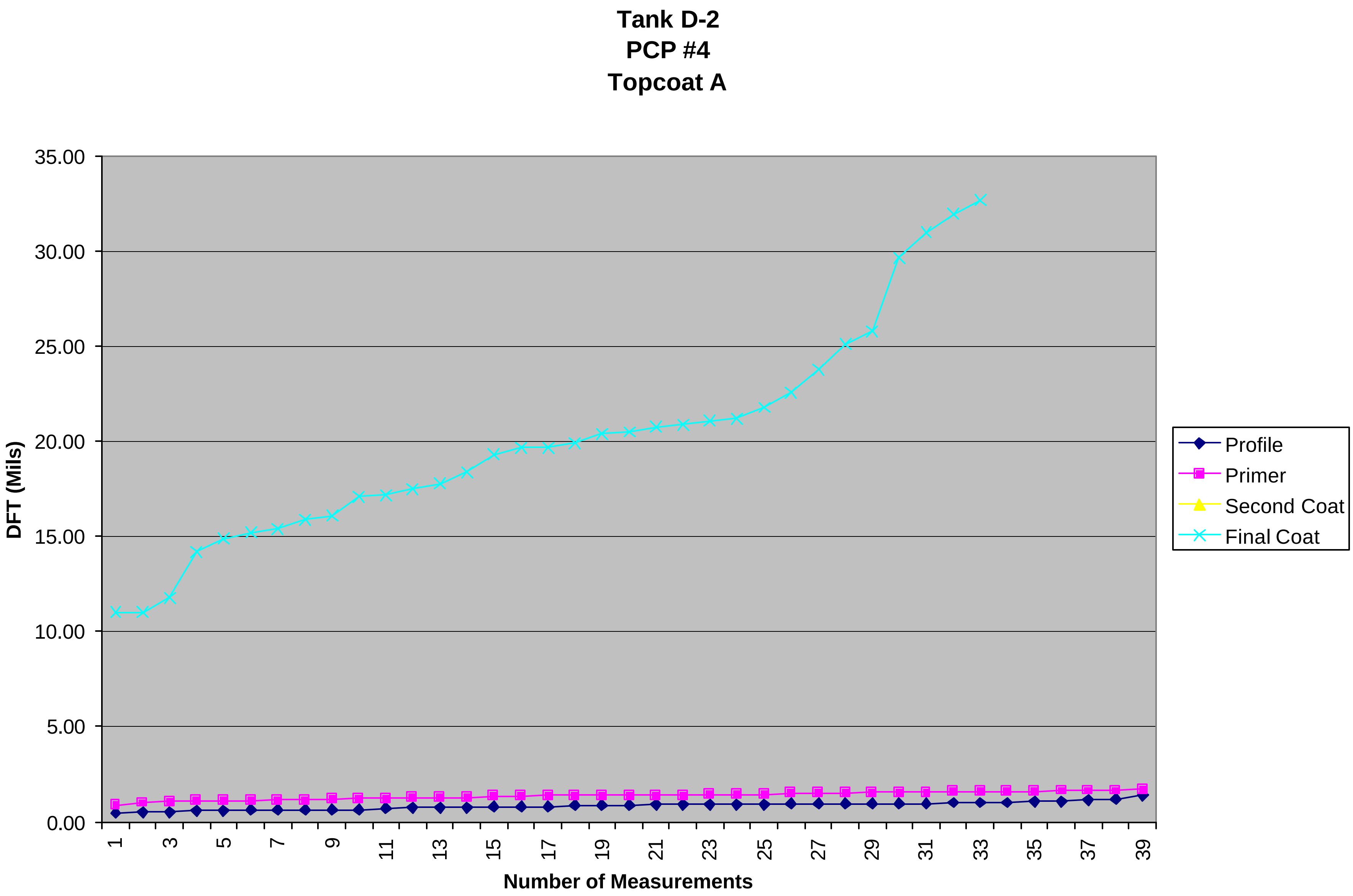

Tank C-1
PCP # 3
Topcoat F MIL-P-23236
DFT (Mils)
Number of Measurements
Profile
Primer
Second Coat
Final Coat
25.00
20.00
15.00
10.00
5.00
0.00
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39


Tank C-2
PCP # 3
Topcoat D
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
DFT (Mils)
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
Number of Measurements
Profile
Primer
Second Coat
Final Coat


Tank C-3 Control #1
PCP Totally Removed
Topcoat F MIL-P-23236
DFT (Mils)
25.00
20.00
15.00
10.00
5.00
0.00
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
Number of Measurements
Profile
Primer
Second Coat
Final Coat



Tank D-1
PCP # 4
Topcoat C
DFT (Mils)
25.00
20.00
15.00
10.00
5.00
0.00
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
Number of Measurements
Profile
Primer
Second Coat
Final Coat



Tank D-2
PCP #4
Topcoat A
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
DFT (Mils)
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
Number of Measurements
Profile
Primer
Second Coat
Final Coat

Tank D-3
PCP Completely Removed Control #2
Mil=P-24441, Type IV